

SERVICE MANUAL

Number 27

MARINE ENGINES

V-8 Diesel
D7.3L D-Tronic

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90-861784 998

MerCruiser #27 V-8 Diesel D7.3L D-Tronic

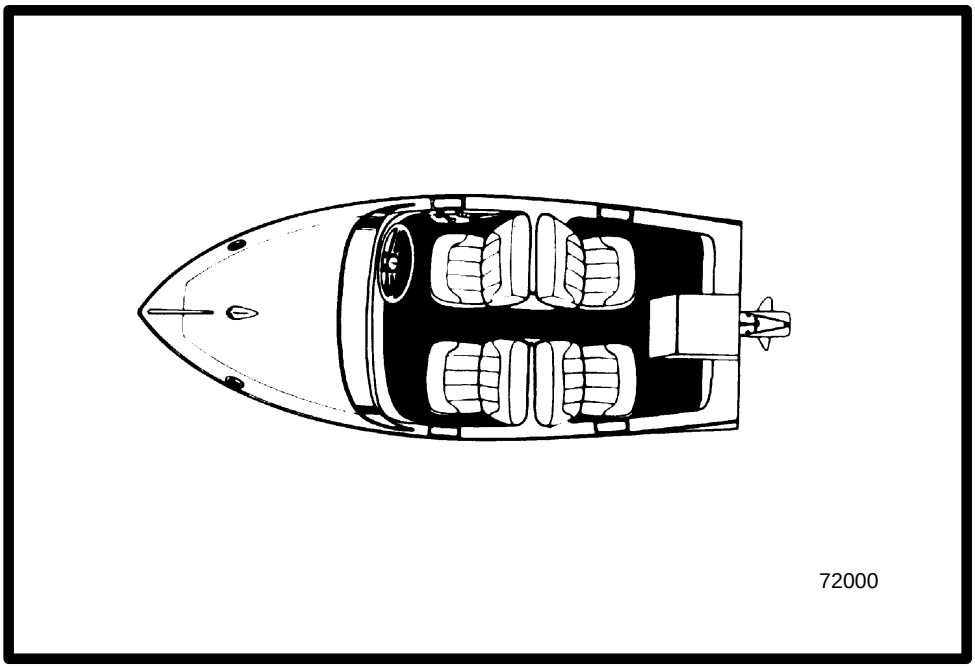
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MerCruiser #27 V-8 Diesel D7.3L D-Tronic

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IMPORTANT INFORMATION

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GENERAL INFORMATION

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Introduction

This comprehensive overhaul and repair manual is designed as a service guide for the models previously listed. It provides specific information, including procedures for disassembly, inspection, assembly and adjustment to enable dealers and service mechanics to repair and tune these engines.

Before attempting repairs, it is suggested that the procedure first be read through to gain knowledge of the methods and tools used and the cautions and warnings required for safety.

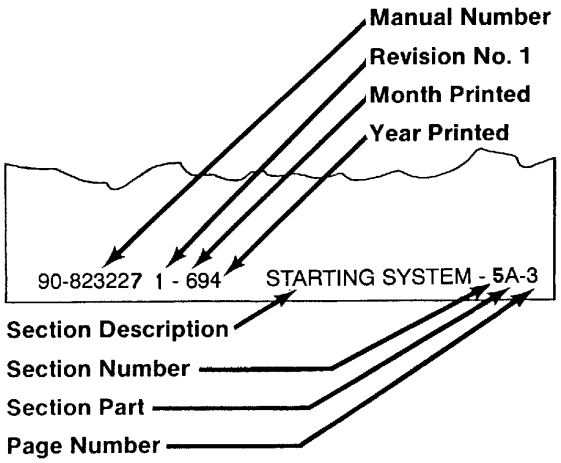
How to Use This Manual

This manual is divided into sections which represent major components and systems.

Some sections are further divided into parts which more fully describe the component.

Page Numbering

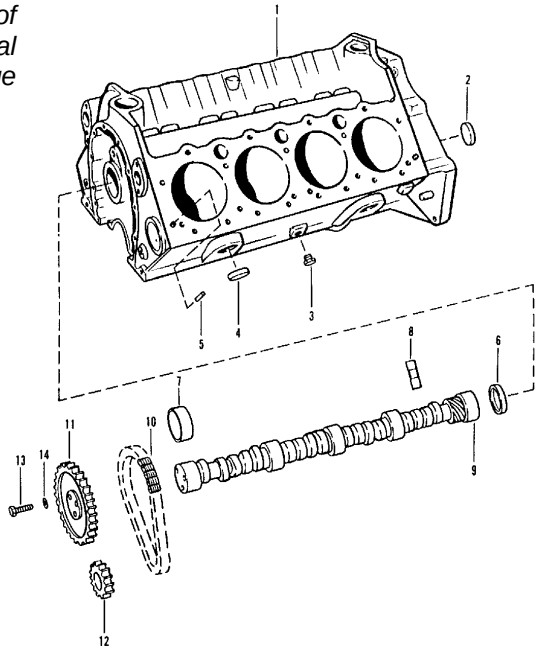
Two number groups appear at the bottom of each page. Following is an example and description.



72426

How to Read Parts Manual

NOTE: *The following is representative of a page from a MerCruiser Parts Manual and is not intended to be an actual page from a specific Parts Manual.*



73287

M0033-D8

CYLINDER BLOCK AND CAMSHAFT

a PART NO.	b REF. NO.	c DESCRIPTION	d QUAN.
841-81631	1	CYLINDER BLOCK ASSEMBLY	1
N.S.S.	2	PLUG, expansion (1-1/4″)	2
22-87238	3	DRAIN COCK, cylinder block	2
19-34270	4	PLUG, expansion - cylinder block (1-5/8″ Diameter)	8
17-35465	5	PIN, dowel - block to head (5/16″ Diameter)	4
22-72640	6	PLUG, expansion - camshaft bearing hole	1
23-85674	7	BEARING UNIT, camshaft (set)	1
72638	8	LIFTER, hydraulic valve	16
431-5943	9	CAMSHAFT	1
35378	10	CHAIN, camshaft timing	1
43-35338	11	SPROCKET, camshaft timing	1
43-48338	12	SPROCKET, crankshaft timing	1
10-34505	13	BOLT, camshaft timing sprockets (3/4″)	3
12-39167	14	WASHER, camshaft timing sprocket bolt	3

e 841-8163 Cylinder Block Assembly includes only standard pistons, piston rings, crankshaft bearings and camshaft bearings.

A. **Part Number:** For part ordering - Note N.S.S. for Reference Number 2, Plug, expansion - that means Not Sold Separately by Mercury Marine.

B. **Reference Number:** For part shown on exploded parts view.

C. **Description:** This is the most important column because it gives:

1) Description of Part: Ref. No. 1 is a Cylinder Block Assembly, No. 9 is a Camshaft, etc.

2) What parts are included with a certain part: Notice how the Description of Part, for Ref. Nos. 1 and 8 through 14, are at the left side of the column. Description of Part for Ref. Nos. 2 through 7 are indented under “Cylinder Block Assembly”. If Ref. No. 1 (Cylinder Block Assembly) was ordered, all indented parts (Ref. Nos. 2 through 7) would come with the part. Ref. Nos. 8 through 14 would not come with Ref. No. 1 and would have to be ordered separately. If two Cylinder Blocks were listed, both cylinder blocks would come with the indented parts. In some cases, an indented part will have another part indented under it. The second indented part will come with the first indented part.

3) Serial number break: If serial number information is listed, check product serial number to ensure that correct part is ordered.

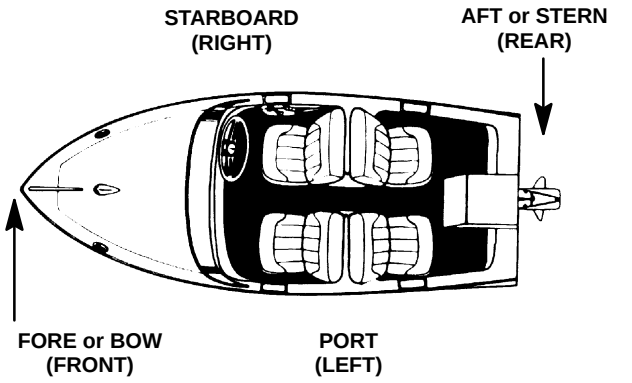
4) Special information: Many times special information will be shown after description, such as: L.H. Rotation, R.H. Rotation, Filter Up, Filter Down, etc. This will help in selecting the correct part.

D. **Quantity:** Quantity that has to be ordered.

E. **Special Information Block:** Additional information, part numbers for gasket sets, etc.

Directional References

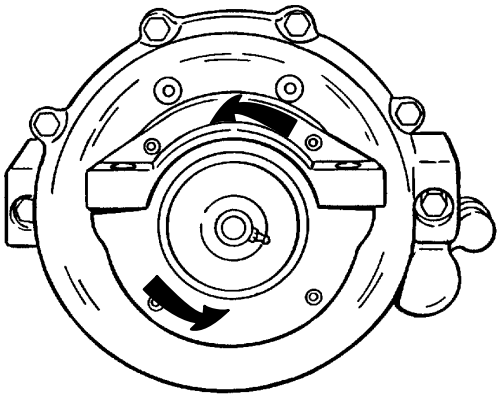
Front of boat is bow; rear is stern. Starboard side is right side; port side is left side. In this maintenance manual, all directional references are given as they appear when viewing boat from stern looking toward bow.



72000

Engine Rotation

Engine rotation is determined by observing flywheel rotation from the rear (stern end) of the engine looking forward (toward water pump end). Propeller rotation is not necessarily the same as engine rotation. When ordering replacement engine, short blocks or parts for engine, be certain to check engine rotation. Do not rely on propeller rotation in determining engine rotation.

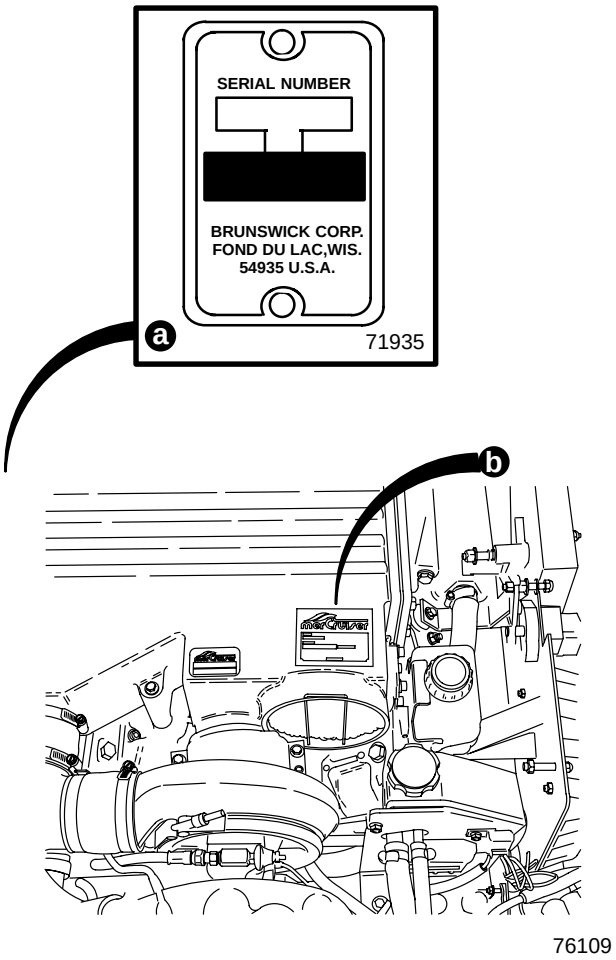


73258

a - Standard Left-Hand Rotation

Engine Serial Number and Identification Locations

The permanent engine serial number is stamped on the top left side of the engine block. The self-adhesive serial number plate is located on the top side of the aftercooler.



a - Riveted Serial Number Plate (Top, PortSide of Engine Block)

b - Self-Adhesive Serial Number Plate Applied to Top of Aftercooler

Propeller Information

Refer to the “Propeller” section in appropriate MerCruiser Stern Drive Service Manual, or order publication P/N 90-86144-92. “Everything you need to know about propellers.”

Changing diameter, pitch or coupling of a propeller will affect engine RPM and boat performance. The blade configuration also will affect performance. Two like propellers, same pitch and diameter, from two different manufacturers also will perform differently.

It is the responsibility of the boat manufacturer and/or selling dealer to equip the boat with the correct propeller to allow the engine to operate within its specified RPM range at wide-open-throttle (W.O.T.).

Because of the many variables of boat design and operation, only testing will determine the best propeller for the particular application.

To test for correct propeller, operate boat (with an average load onboard) at W.O.T. and check RPM with an accurate tachometer. Engine RPM should be near top of the specified range so that, under heavy load, engine speed will not fall below specifications.

If engine exceeds the specified RPM, an increase in pitch and/or diameter is required.

If engine is below rated RPM, a decrease in pitch and/or diameter is required.

Normally, a change of approximately 100 to 150 RPM will be achieved for each single pitch change of a propeller.

⚠CAUTION

If a propeller is installed that does not allow engine RPM to reach the specified full-throttle RPM range, the engine will “labor” and will not produce full power. Operation under this condition will cause excessive fuel consumption and engine overheating. On the other hand, installation of a propeller, that allows engine to run above the specified RPM limit, will cause excessive wear on internal engine parts which will lead to premature engine failure.

Engine Initial Break-In Procedure

It is especially important that the following procedure be used on new and rebuilt diesel engines. This break-in procedure allows the proper seating of the pistons and rings, which greatly reduces the likelihood of problems.

IMPORTANT: It is recommended that the boat not be accelerated hard until this procedure has been completed.

IMPORTANT: Never operate the starter motor longer than 15 seconds at a time, to avoid overheating the starter motor. If engine does not start, wait 1 minute to allow the starter motor to cool; then, repeat starting procedure.

Initial Break-In Procedure is as follows:

1. Refer to owner’s manual and start engine. Allow engine to idle until engine has reached normal operating temperature.
2. Run engine in gear for 3 minutes at each of the following RPMs: 1200 RPM, 2400 RPM and 3000 RPM.
3. Run engine in gear for 3 minutes at each of the following RPMs: 1500 RPM, 2800 RPM and 3200 RPM.
4. Run engine in gear for 3 minutes at each of the following RPMs: 1800 RPM, 3000 RPM and Maximum Rated Full-Throttle RPM.

Engine 20-Hour Break-In Period

IMPORTANT: The first 20 hours of operation is the engine break-in period. Correct break-in is essential to obtain minimum oil consumption and maximum engine performance. During this break-in period, the following rules must be observed:

The first 20 hours of operation is the engine (new or rebuilt) break-in period. During this period, it is extremely important that the engine is operated as outlined in the following.

1. DO NOT operate engine below 1500 RPM for extended periods of time during the first 10 hours. During this period, shift into gear as soon as possible after starting engine and advance throttle so that RPM is above 1500 (provided that conditions permit safe operation at this speed).

2. DO NOT operate at any one constant speed for extended periods of time.
3. DO NOT exceed 75% of full throttle during the first 10 hours except during the Engine Initial Break-In Procedure. During the next 10 hours, occasional operation at full throttle (5 minutes at a time maximum) is permissible.
4. AVOID full throttle accelerations from stopped position.
5. DO NOT operate at full throttle until engine reaches normal operating temperature.
6. OBSERVE INSTRUMENTATION carefully. If an abnormal reading occurs, stop engine immediately and determine cause.
7. FREQUENTLY CHECK crankcase oil level and add oil if necessary. It is normal for oil consumption to be somewhat high during the break-in period.
8. AT END OF THE 20-HOUR BREAK-IN PERIOD, drain oil from crankcase and replace oil and filter. Fill crankcase with correct grade and viscosity oil.

Water Testing New Engines

Use care during the first 20 hours of operation on new MerCruiser engines or possible engine failure may occur. If a new engine has to be water-tested at full throttle before the break-in period is complete, follow this procedure ONLY AFTER the engine INITIAL BREAK-IN PROCEDURE has been completed.

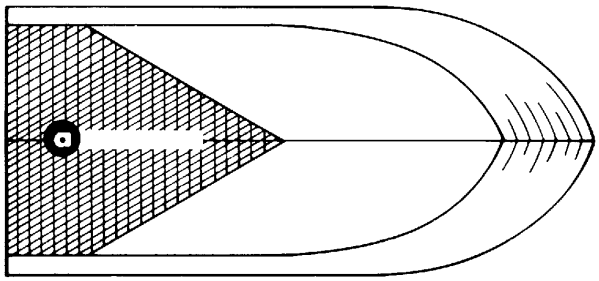
1. Start engine and run at idle RPM until normal operating temperature is reached.
2. Run boat up on plane.
3. Advance engine RPM (in 200 RPM increments) until engine reaches its maximum rated RPM.

IMPORTANT: Do not run at maximum RPM for more than 2 minutes.

Boat and Engine Performance

Boat Bottom

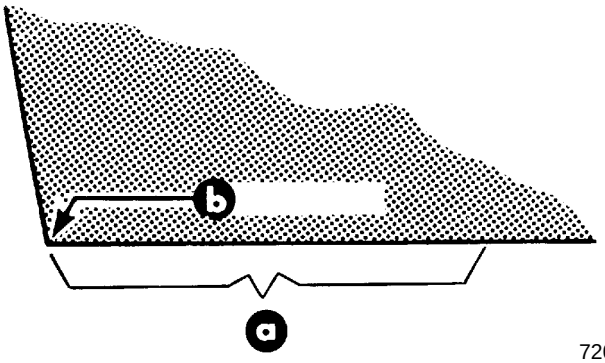
For maximum speed, a boat bottom should be as flat as possible in a fore-aft direction (longitudinally) for approximately the last 5 ft. (1.5 m).



72002

a - Critical Bottom Area

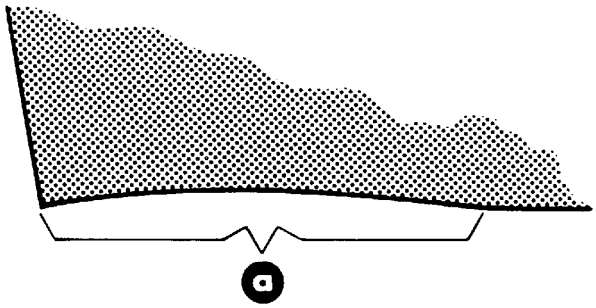
For best speed and minimum spray, the corner between the bottom and the transom should be sharp.



72003

a - Flat
b - Sharp Corner

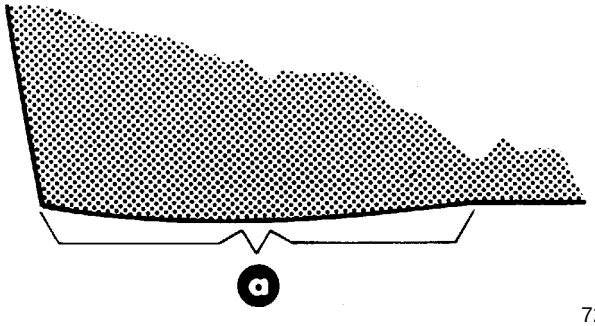
The bottom is referred to as having a “hook” if it is concave in the fore-and-aft direction. A hook causes more lift on the bottom near the transom and forces the bow to drop. This increases wetted surface and reduces boat speed. A hook, however, aids in planing and reduces any porpoising (rhythmical bouncing) tendency. A slight hook is often built in by the manufacturer. A hook also can be caused by incorrect trailering or storing the boat with support directly under the transom.



72004

a - Hook

A “rocker” is the reverse of a hook. The bottom is convex or bulged in the fore-and-aft direction. It can cause the boat to porpoise.



72005

a - Rocker

Any hook, rocker or surface roughness on the bottom, particularly in the all-important center-aft portion will have a negative effect on speed, often several miles per hour on a fast boat.

Marine Fouling

Fouling is an unwanted build-up (usually animal-vegetable-derived) occurring on the boat’s bottom and drive unit. Fouling adds up to drag, which reduces boat performance. In fresh water, fouling results from dirt, vegetable matter, algae or slime, chemicals, minerals and other pollutants. In salt water, barnacles, moss and other marine growth often produce dramatic build-up of material quickly. Therefore, it is important to keep the hull as clean as possible in all water conditions to maximize boat performance.

Special hull treatments, such as anti-fouling paint, will reduce the rate of bottom fouling. However, due to the fact that drive units (outboard or stern drive) are made primarily of aluminum, be sure to select an anti-fouling paint having a copper-free, organo-tin base. The BIS (Tri Butyl Tin) Adipate (TBTA) base paint will not set up a galvanic corrosion “cell” as it is completely compatible with aluminum and avoids any electrolysis problems connected with many other paints. Applied according to instructions, it also is very effective.

Weight Distribution

Weight distribution is extremely important; it affects a boat’s running angle or attitude. For best top speed, all movable weight - cargo and passengers - should be as far aft as possible to allow the bow to come up to a more efficient angle (3 to 5 degrees). On the negative side of this approach is the problem that, as weight is moved aft, some boats will begin an unacceptable porpoise.

Secondly, as weight is moved aft, getting on plane becomes more difficult.

Finally, the ride in choppy water becomes more uncomfortable as the weight goes aft. With these factors in mind, each boater should seek out what weight locations best suit his/her needs.

Weight and passenger loading placed well forward increases the “wetted area” of the boat bottom and, in some cases, virtually destroys the good performance and handling characteristics of the boat. Operation in this configuration can produce an extremely wet ride, from wind-blown spray, and could even be unsafe in certain weather conditions or where bow steering may occur.

Weight distribution is not confined strictly to fore and aft locations, but also applies to lateral weight distribution. Uneven weight concentration to port or starboard of the longitudinal centerline can produce a severe listing attitude that can adversely affect the boat's performance, handling ability and riding comfort. In extreme rough water conditions, the safety of the boat and passengers may be in jeopardy.

Water in Boat

When a boat loses performance, check bilge for water. Water can add considerable weight to the boat, thereby decreasing the performance and handling.

Make certain that all drain passages are open for complete draining.

How Elevation And Climate Affect Performance

NOTE: *Engines equipped with EDI (D-Tronic engines) reduce the effects of changes in elevation and climate by automatically adjusting fuel flow for weather conditions and elevation. EDI engines however, do not compensate for increased loading or hull conditions.*

Generally, elevation has a very noticeable effect on the wide-open-throttle power of an engine. Since air (containing oxygen) gets thinner as elevation increases, the engine begins to starve for air. Humidity, barometric pressure and temperature do have a noticeable effect on the density of air. Heat and humidity thin the air. This condition can become particularly annoying when an engine is propped out on a cool, dry day in spring and later, on a hot, sultry day in August, doesn't have its old zip.

Although some performance can be regained by dropping to a lower-pitch propeller, the basic problem still exists. In some cases, a gear-ratio change to more reduction is possible and very beneficial.

Summer conditions of high temperature, low barometric pressure and high humidity all combine to reduce the engine power. This, in turn, is reflected in decreased boat speeds, as much as 2 or 3 miles per hour in some cases. Nothing will regain this speed for the boater, but the coming of cool, dry weather.

In pointing out the practical consequences of weather effects, an engine -- running on a hot, humid summer day -- may encounter a loss of as much as 14% of the horsepower it would produce on a dry brisk spring or fall day. With the drop in available horsepower, this propeller will, in effect, become too large. Consequently, the engine operates at less than its recommended RPM. This will result in further loss of horsepower at the propeller with another decrease in boat speed. This secondary loss, however, can be somewhat regained by switching to a lower-pitch propeller that allows the engine to again run at recommended RPM.

For boaters to realize optimum engine performance under changing weather conditions, it is essential that the engine be propped to allow it to operate at or near the top end of the recommended maximum RPM range at wide-open-throttle with a normal boat load.

Not only does this allow the engine to develop full power, but equally important is the fact that the engine also will be operating in an RPM range that discourages damaging detonation. This, of course, enhances overall reliability and durability of the engine.

Recommended Operation/Duty Cycle

It is the operator's responsibility to operate within the following recommended operational capability, or duty cycle, as applicable to engine and installation:

- **Pleasure Duty**

1. Operated at rated power and rated speed for short periods of time.
2. Annual operating time is not to exceed 500 hours.

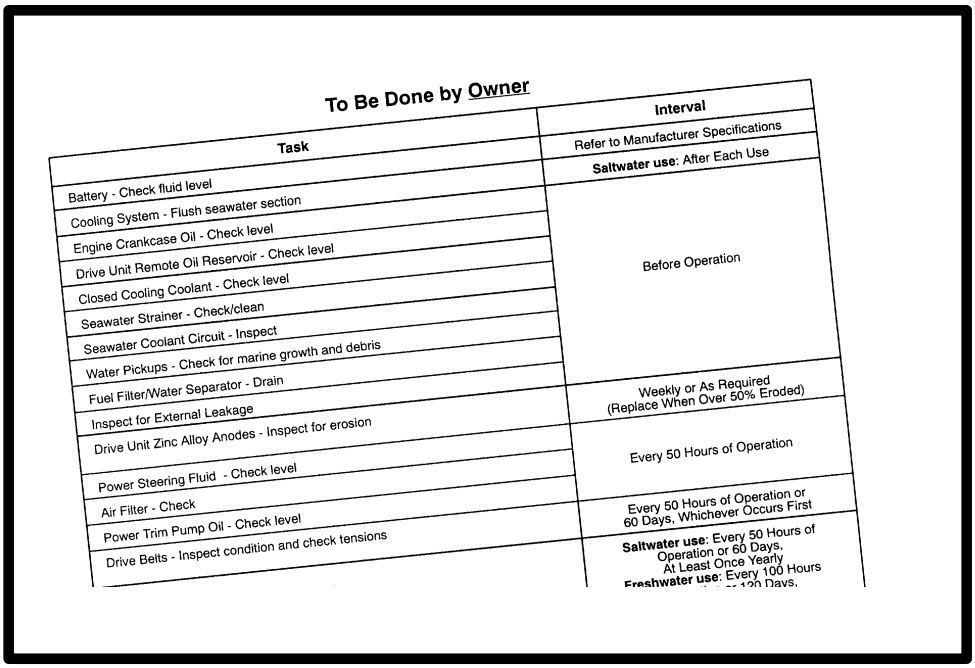
NOTE: *Pleasure duty rating applies to high performance-type boats, or boats with planing hulls where acceleration and top speed are of primary importance. This rating is reserved for privately-owned yachts, or recreational power boats in non-revenue applications.*

IMPORTANT: Damage caused by improper application or failure to operate within the operational capability, or duty cycle, will not be covered by the MerCruiser Diesel Limited Warranty - U.S.A. and Canada, nor by the MerCruiser Diesel International Warranty.

IMPORTANT INFORMATION

1

B



To Be Done by Owner

Task	Interval
Battery - Check fluid level	Refer to Manufacturer Specifications
Cooling System - Flush seawater section	**Saltwater use**: After Each Use
Engine Crankcase Oil - Check level	Before Operation
Drive Unit Remote Oil Reservoir - Check level	
Closed Cooling Coolant - Check level	
Seawater Strainer - Check/clean	
Seawater Coolant Circuit - Inspect	
Water Pickups - Check for marine growth and debris	
Fuel Filter/Water Separator - Drain	
Inspect for External Leakage	Weekly or As Required (Replace When Over 50% Eroded)
Drive Unit Zinc Alloy Anodes - Inspect for erosion	Every 50 Hours of Operation
Power Steering Fluid - Check level	
Air Filter - Check	
Power Trim Pump Oil - Check level	Every 50 Hours of Operation or 60 Days, Whichever Occurs First
Drive Belts - Inspect condition and check tensions	**Saltwater use**: Every 50 Hours of Operation or 60 Days, At Least Once Yearly **Freshwater use**: Every 100 Hours

MAINTENANCE

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Maintenance Schedule

⚠ WARNING

Always disconnect battery cables from battery BEFORE working around electrical system components to prevent injury to yourself or damage to electrical system should a wire be accidentally shorted.

NOTE: *Refer to appropriate Stern Drive Service Manual for information and procedures on stern drive maintenance items listed.*

SCHEDULED MAINTENANCE TO BE PERFORMED BY OWNER/OPERATOR

REQUIRED SERVICE	INTERVAL
Check engine oil level.	Before Operation
Check drive unit gear lube monitor.	
Check closed coolant level.	
Check water pickups for marine growth or debris.	
Drain fuel filter.	
Check/Clean seawater strainer.	Before Operation/Clean As Required
Inspect drive unit alloy anodes for erosion (Replace when over 50% eroded).	Weekly or As Required
Flush seawater section of cooling system.	**Saltwater Use**: After Each Use
Check power trim pump oil level.	Every 50 Hours of Use
Check power steering fluid level.	
Clean air filter element.	Every 50 Hours of Operation, or as Conditions Require
Inspect condition and check tension of drive belts.	Every 50 Hours of Operation or 60 Days - Whichever Occurs First
Lubricate propeller shaft.	**Saltwater Use:** Every 50 Hours of Operation or 60 Days, Whichever Occurs First **Freshwater Use:** Every 100 Hours of Operation or 120 Days, Whichever Occurs First
Replace fuel filter.	Every 100 Hours of Operation or Once A Year, Whichever Occurs First
Replace air filter element.	Every 200 Hours of Operation, or Once a Year, Whichever Occurs First
Check sacrificial anode (in heat exchanger) - Replace when over 50% eroded.	Once a Year
Check sacrificial anode (in engine oil cooler) - Replace when over 50% eroded.	
Spray power package exterior surfaces with Quicksilver Corrosion Guard.	
Clean and paint power package exterior surfaces.	As Necessary
Check battery fluid level.	Refer to Battery Manufacturer Specifications

Maintenance Schedule (Continued)

SCHEDULED MAINTENANCE TO BE PERFORMED BY DEALER

REQUIRED SERVICE	INTERVAL
Change engine oil and filter.	After 20-Hour Break-In Period, Then, for **Pleasure-craft Use[1]:** Every 100 Hours of Use or 120 Days, Whichever Occurs First.
Lubricate engine coupling and universal joint shaft splines.	Every 50 Hours of Operation or 60 Days, Whichever Occurs First
Check engine alignment and mounting hardware.	Every 100 Hours of Operation
Change transmission fluid.	
Change Stern Drive Unit oil including gear lube monitor oil.	Every 100 Hours of Operation or 120 Days, Whichever Occurs First
Retorque gimbal ring clamping U-bolt to 50 - 55 lb. ft. (67 - 74 N·m).	Every 100 Hours of Operation or Once a Year, Whichever Occurs First
Clean, inspect and test the closed cooling system pressure cap.	
Replace coolant (using only Quicksilver Premixed Marine Engine Coolant).	Every 200 Hours of Operation or Once a Year, Whichever Occurs First
Clean heat exchangers.	
Lubricate universal joint cross bearings.	
Check and adjust idle RPM.	Once a Year
Clean aftercooler core.	Every 500 Hours of Operation
Replace drive belts.	
Inspect cooling system hoses and clamps.	**Saltwater use:** Every 50 hours of operation or 60 days, Whichever Occurs First **Freshwater use:** Every 100 hours of operation or 120 days, Whichever Occurs First
Inspect exhaust system and clamps.	
Inspect and lubricate shift/throttle cables and linkage.	
Check electrical system for loose or damaged wiring.	
Lubricate transom gimbal bearing.	
Lubricate and inspect steering system for loose, damaged or missing parts.	
Ground Wire Circuit continuity - Check components for loose connections, broken or frayed wires.	
Disassemble and inspect seawater pump.	At Least Once yearly
Clean fuel tank.	Every 1000 Hours of Operation

NOTE 1: For an explanation of Pleasure Craft usage refer to SECTION 1A - “Recommended Operation/Duty Cycle”.

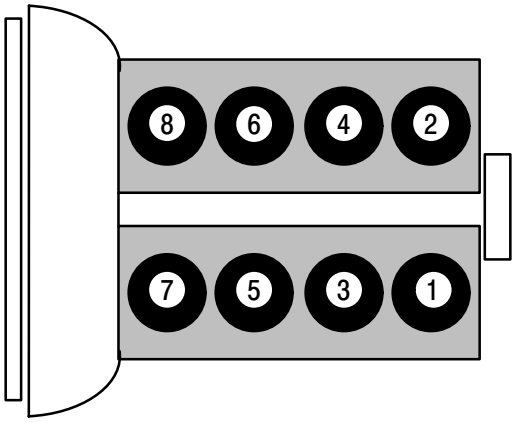
Specifications

Engine

ITEM / MODEL		SPECIFICATION
Crankshaft Horsepower (Kilowatts) [1]		300 (224)
Propeller Shaft Horsepower (Kilowatts) [1]		270 (201)
Engine Type		V-8 Cylinder Diesel
Displacement		444 cu. in. (7.3 L)
Firing Order		1-2-7-3-4-5-6-8
Bore		4.11 in. (104.39 mm)
Stroke		4.18 in. (106.20 mm)
Compression Ratio		17.5:1
Valve Clearance (Intake/ Exhaust)		Non-Adjustable (Hydraulic)
Maximum Pressure Difference Between Cyl.		75 PSI (517 kPa)
Maximum Governed WOT RPM		3950 ± 50
Maximum WOT RPM		3800
Idle RPM in Forward Gear		625 ± 25
Oil Pressure:	650 RPM	10 PSI [0.7 bar (69 kPa)] Minimum
	3800 RPM	40 - 70 PSI [2.8 - 4.8 bar (276 - 482 kPa)]
Oil Temperature		250° F (121° C) Maximum
Thermostat		170° F (77° C)
Coolant Temperature		170° - 210° F (77° - 99° C)
Electrical System		12-volt Negative (–) Ground
Alternator Rating		949W, 14.6v, 65A
Recommended Battery Rating (Cold Cranking Amperage)		12v, 1500 cca or 300 Ah
Starter	Delco, Series 28MT	12v, 2.4 kW

[1] Power rated in accordance with NMMA Procedure - ISO 3046 (Technically Identical to ICOMIA 28-83).

Firing Order



Firing Order: 1-2-7-3-4-5-6-8

Fluid Capacities

NOTICE

All capacities are approximate fluid measures in U.S. Quarts (Litres).

ITEM		SPECIFICATION
Total Oil-Filling Capacity[1]		16.5 (15.6)
Oil Drainage:	from oil pan	14.5 (13.7)
	from oil filter	1 (1)
	from oil cooler	1 (1)
Drive Unit Oil Capacity (With Gear Lube Monitor) [1]		3 (3)
Closed Cooling System		26 (24.5)
Seawater Cooling System [2]		15 (14)

[1] Always use dipstick to determine exact quantity of oil or fluid required.

[2] Seawater cooling system capacity information is for cold weather or extended storage use only.

Fluid Specifications

Diesel Fuel

⚠WARNING

FIRE HAZARD: Fuel leakage from any part of the fuel system can be a fire hazard which can cause serious bodily injury or death. Careful periodic inspection of entire fuel system is mandatory, particularly after storage. All fuel components including fuel tanks, whether plastic, metal or fiberglass, fuel lines, primers, fittings, and fuel filters should be inspected for leakage, softening, hardening, swelling or corrosion. Any sign of leakage or deterioration requires replacement before further engine operation.

⚠WARNING

Under *no circumstances* should gasoline, gasohol and/or alcohol be mixed with diesel fuel for any reason. This mixture of gasoline, gasohol and/or alcohol with diesel fuel is highly flammable and produces a significant risk to the user.

IMPORTANT: Use of improper or water-contaminated diesel fuel will damage your engine seriously. Use of improper fuel is considered misuse of engine, and damage caused thereby will not be covered by warranty.

Grade 2-D diesel fuel is required, meeting ASTM Standards D975 (or fuel rated Diesel DIN 51601), and having a minimum cetane rating of 45.

The cetane number is a measure of the ignition quality of diesel fuel. Increasing the cetane number will not improve overall engine performance, but it may be necessary to raise the cetane rating for low temperature or high altitude use.

NOTE: *If your engine suddenly becomes noisy after a fuel fill, you possibly received substandard fuel with a low cetane rating.*

Sulphur content of the above fuel is rated at 0.50% by weight, maximum (ASTM). Limits may vary in countries outside of the United States.

On intermittent use engines, high sulphur content diesel fuel will greatly increase:

- Corrosion of metal parts.
- Deterioration of elastomer and plastic parts.
- Corrosion and extensive damage, and excessive wear of internal engine parts, particularly bearings.
- Starting and operating difficulties.

DIESEL FUEL IN COLD WEATHER

Unaltered diesel fuels thicken and “gel” in cold temperatures, unless treated. Virtually all diesel fuels are “climatized” to allow their use in the particular region for that time of the year. If it becomes necessary to further treat diesel fuel, it is the owner/operator’s responsibility to add a commercial “standard brand” “anti-gel” diesel fuel additive, following that product’s directions.

Crankcase Oil

To help obtain optimum engine performance and to provide maximum protection, the engine requires engine oil with a rating of 15W-40 - API - CG4/SJ.

For all temperature operation use 15W-40 oil.

Power Steering Fluid

Use Quicksilver Power Trim and Steering Fluid, or automatic transmission fluid (ATF), Dexron, Dexron II.

Coolant for Closed Cooling System

⚠CAUTION

Alcohol or Methanol base antifreeze or plain water are not recommended for use in closed cooling section of cooling system at any time.

Because diesel engines are high compression engines and related higher engine operating temperatures are created, the closed cooling system and engine, including related cooling passages must remain as clean as possible to provide adequate engine cooling. This can only be assured by using the proper anti-freeze, water, additives and inhibitors. It is recommended that the closed cooled section of the cooling system be filled with a low, or no, silicate formula of ethylene glycol antifreeze in solution with deionized water. A low silicate formula prevents antifreeze separation which causes a silicate gelatin to form. This gelatin will block engine and heat exchanger passages causing engine overheating.

The coolant, if not premixed, should be mixed before being added to the closed cooling system using a proper anti-freeze together with deionized water. Common tap water or softened water contains unwanted minerals which can leave large deposits in the system that restrict the cooling system efficiency. In addition, additives and inhibitors introduced into acceptable coolant solutions will form a protective film on internal passages and provide protection against internal cooling system erosion.

The closed cooling section should be kept filled year-round with an acceptable anti/freeze/coolant solution. Do not drain closed cooled section for storage, as this will promote rusting of internal surfaces. If engine will be exposed to freezing temperatures, make sure that closed cooled section is filled with a properly mixed antifreeze/coolant solution, to protect engine and closed cooling system to lowest temperature to which they will be exposed.

IMPORTANT: The anti-freeze/coolant used in these marine engines must be a low (or no) silicate ethylene glycol, containing special additives, and deionized, purified water. Using other types of engine coolant may cause fouling of the heat exchangers, and overheating of the engine. Do not combine different types of coolants without knowing that they are compatible. Refer to the coolant manufacturer's instructions.

Some acceptable types of anti-freeze/coolants are listed in the following table. Refer to "Maintenance Schedules" for respective change intervals.

DESCRIPTION	PART NUMBER
Quicksilver Premixed Marine Engine Coolant	92-813054A2
Extended Life Anti-Freeze/ Coolant	Obtain Locally
Fleetguard Complete	

Maintaining Crankcase Oil Level

OVERFILLED ENGINE CRANKCASE

Overfilled crankcases (oil level being too high) can cause a fluctuation or drop in oil pressure and rocker arm "clatter" on MerCruiser engines. The over-full condition results in the engine crankshaft splashing and agitating the oil, causing it to foam (become aerated). The aerated oil causes the hydraulic valve lifters to "bleed down". This, in turn, results in rocker arm "clatter" and loss of engine performance, due to the valves not opening properly.

Care must be taken when checking engine oil level. Oil level must be maintained between the ADD mark and the FULL mark on the dipstick. To ensure that you are not getting a "false reading," make sure the following steps are done before checking the oil level.

- Boat "at rest" in the water, or
- If boat is on a trailer, raise or lower bow until the boat is setting at the approximate angle that it would be if setting "at rest" in the water.
- Allow sufficient time for oil to drain into the crankcase if engine has just been run or oil has just been added.

Checking Engine Oil Level/Filling

IMPORTANT: ENGINE CRANKCASE OIL MUST BE CHECKED AT INTERVALS SPECIFIED IN "MAINTENANCE SCHEDULE" CHART. It is normal for an engine to use a certain amount of oil in the process of lubrication and cooling of the engine. The amount of oil consumption is greatly dependent upon engine speed, with consumption being highest at wide-open-throttle and decreasing substantially as engine speed is reduced.

1. Stop engine and allow boat to come to a rest.
2. Allow oil to drain back into oil pan - approximately 5 minutes.
3. Remove dipstick. Wipe clean and reinstall. Insert dipstick all the way into dipstick tube.
4. Remove dipstick and note the oil level.
5. Oil level must be between the FULL and ADD marks.
6. If oil level is below ADD mark, proceed to Steps 7 and 8.
7. Remove oil filler cap from valve rocker arm cover.
8. Add required amount of oil to bring level up to, but not over, the FULL mark on dipstick.

Changing Crankcase Oil and Oil Filter

1. Start engine and run until it reaches normal operating temperature.

IMPORTANT: Change oil when engine is warm from operation, as it flows more freely, carrying away more impurities.

2. Stop engine.
3. Remove drain plug from oil pan or from oil drain hose.

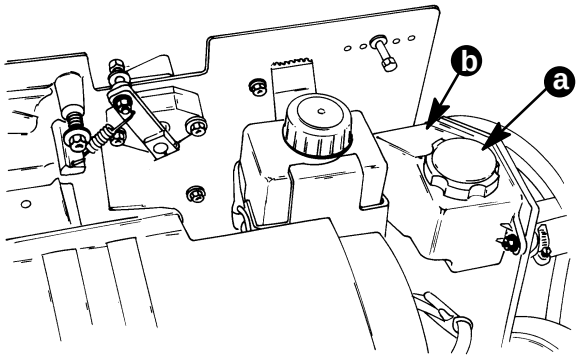
NOTE: *If drain plug is not accessible because of boat construction, oil may be removed through dipstick tube, using a Quicksilver Crankcase Oil Pump. (See Quicksilver Accessory Guide.)*

4. After oil has drained completely, reinstall drain plug (if removed) and tighten securely.
5. Remove and discard oil filter and its sealing ring.
6. Coat sealing ring on new filter with engine oil, and install. Tighten filter securely (following filter manufacturer's instructions). Do not over-tighten.
7. Fill crankcase with oil.
8. Start engine and check for leaks.

Maintaining Power Steering Pump Fluid Level

WITH ENGINE WARM

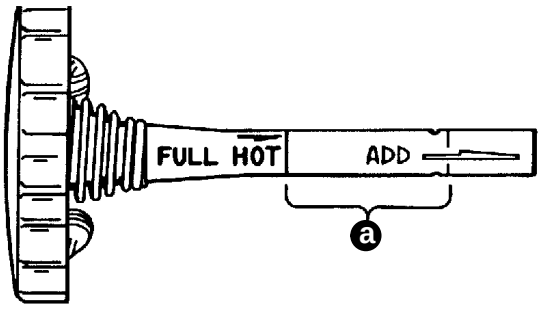
1. Stop engine and position drive unit so that it is straight back.
2. Remove fill cap/dipstick from power steering fluid reservoir and note fluid level.



75952

a - Fill Cap/Dipstick
b - Power Steering Reservoir

3. Level should be between the FULL HOT mark and ADD mark on dipstick.



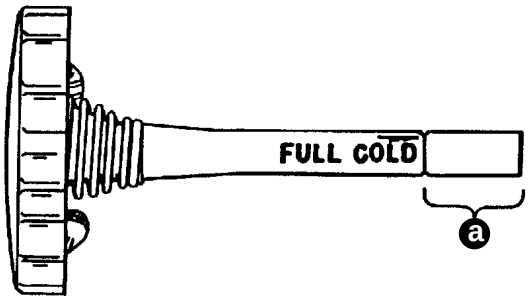
72518

a - Proper Fluid Level with Engine Warm

4. If level is below ADD mark, but fluid is still visible in pump reservoir, add required amount of Quicksilver Power Trim and Steering Fluid or automatic transmission fluid (ATF), Dexron, or Dexron II, through fill cap opening, to bring level up to FULL HOT mark on dipstick. DO NOT OVERFILL.
5. If fluid is not visible in reservoir, a leak exists in the power steering system. Find cause and correct.

WITH ENGINE COLD

1. With engine stopped, position drive unit so that it is straight back.
2. Remove fill cap/dipstick from power steering reservoir and note fluid level.
3. Level should be between FULL COLD mark and bottom of dipstick.



72519

a - Proper Fluid Level with Engine Cold

4. If level is below bottom of dipstick, but fluid is still visible in pump reservoir, add required amount of Quicksilver Power Trim and Steering Fluid or automatic transmission fluid (ATF), Dexron, or Dexron II, through fill cap opening, to bring level up to FULL COLD mark on dipstick. DO NOT OVERFILL.

If fluid is not visible in reservoir, a leak exists in the power steering system. Find the cause and correct as required.

Filling and Bleeding Power Steering System

IMPORTANT: Power steering system must be filled exactly as explained in the following to be sure that all air is bled from the system. All air must be removed, or fluid in pump may foam during operation and be discharged from pump reservoir. Foamy fluid also may cause power steering system to become spongy, which may result in poor boat control.

1. With engine stopped, position drive unit so that it is straight back. Remove fill cap/dipstick from power steering pump. Add Quicksilver Power Trim and Steering Fluid or automatic transmission fluid (ATF), Dexron, or Dexron II, as required, to bring level up to FULL COLD mark on dipstick.

IMPORTANT: Use only Quicksilver Power Trim and Steering Fluid or automatic transmission fluid (ATF), Dexron, or Dexron II in power steering system.

2. Turn steering wheel back and forth to end of travel in each direction several times, then recheck fluid level and add fluid, if necessary.
3. Install vented fill cap.

⚠CAUTION

DO NOT operate engine without water being supplied to seawater pickup pump, or pump impeller may be damaged and subsequent overheating damage to engine may result.

4. Start engine and run at fast idle (1000-1500 RPM) until engine reaches normal operating temperature. During this time, turn steering wheel back and forth to end of travel in each direction several times.
5. Position drive unit so that it is straight back and stop engine. Remove fill cap from pump. Allow any foam in pump reservoir to disperse, then check fluid level and add fluid, as required, to bring level up to FULL HOT mark on dipstick. DO NOT OVERFILL**.** Reinstall fill cap securely.

IMPORTANT: Drive unit must be positioned straight back and power steering fluid must be hot to accurately check fluid level.

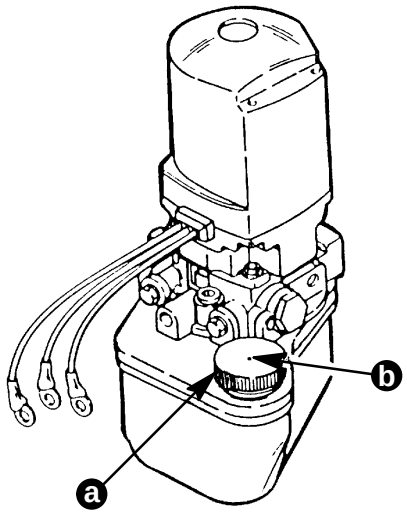
6. If fluid is still foamy (in Step 5), repeat Steps 4 and 5 until fluid does not foam and level remains constant.

Maintaining Power Trim Pump Oil Level

1. Place drive unit in full down/in position.

IMPORTANT: Trim pump reservoir fill cap has a small vent hole in it. Occasionally check to ensure vent is not restricted.

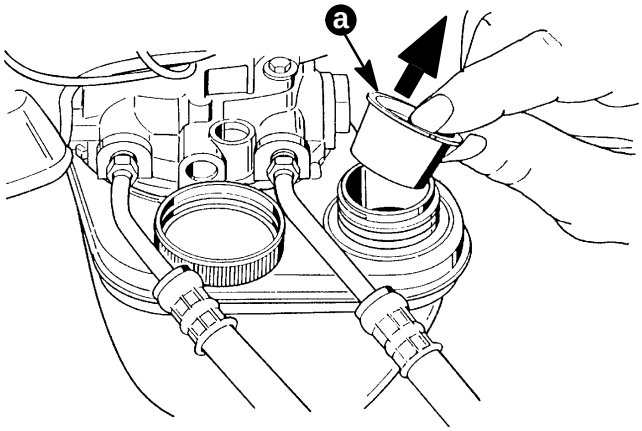
2. Unscrew fill cap.



73182

a - Fill Cap
b - Fill Cap Vent Hole

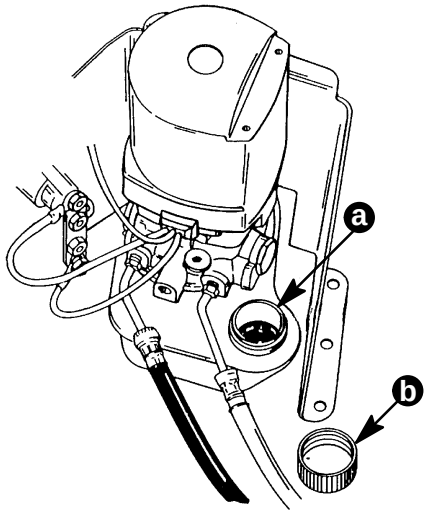
NOTE: *New trim pumps have a shipping "caplug" in the reservoir fill neck. Check to ensure that this caplug is NOT present in filler neck. DISCARD caplug if present.*



73183

a - Caplug

3. Observe oil level. Level must be up to, but not over, bottom of fill neck. Add Quicksilver Power Trim and Steering Fluid if required (or SAE 10W-30 motor oil if Quicksilver Power Trim and Steering Fluid is unavailable) to bring level to bottom of filler neck. Replace fill cap, and tighten when finished with checks.



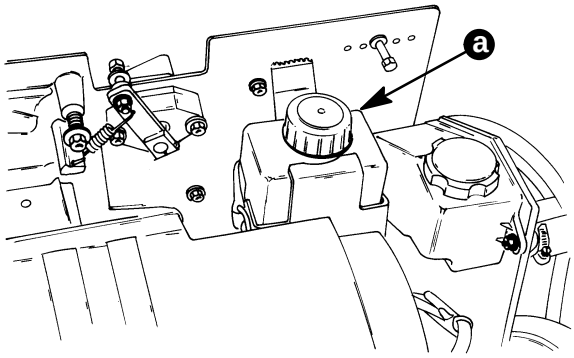
a - Fill Neck
b - Fill Cap

73184

Maintaining Drive Unit Oil (Gear Lube Monitor)

Check gear lube monitor oil level; keep oil level at or near FILL line. Check for water at bottom of monitor, and/or if oil appears a milky-tan. Both conditions indicate a water leak somewhere in the drive unit.

IMPORTANT: If more than 2 oz. (57 grams) of Quicksilver High Performance Gear Lube are required to fill drive unit, a seal may be leaking. Damage to unit may occur due to lack of lubrication.

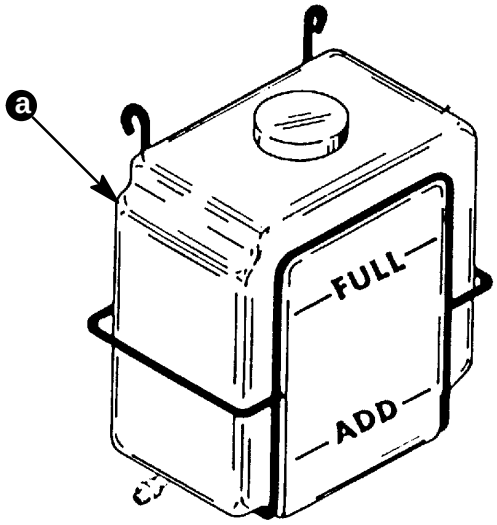


75952

a - Gear Lube Monitor

Maintaining Closed Cooling System Coolant Level

1. Check coolant level in coolant recovery bottle. Coolant level should be between the ADD and FULL marks on coolant recovery reservoir with the engine at normal operating temperature. Add specified coolant as required.



72520

a - Coolant Recovery Reservoir

NOTE: *Coolant recovery system is considered to be functioning properly when coolant level in heat exchanger/coolant tank remains at bottom edge of its filler neck.*

⚠WARNING

Allow engine to cool down before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

2. Periodically, to ensure that coolant recovery system is functioning properly, you should allow engine to cool and then *slowly and carefully* remove coolant tank cap. Coolant level must be to the bottom edge of the tank filler neck. If coolant is low, add coolant as necessary to bring up to proper level. Refer to “Specifications” for proper coolant.

IMPORTANT: When installing pressure cap, be sure to tighten it until it contacts stop on filler neck.

Changing Closed Cooling Fluid

⚠WARNING

Allow engine to cool before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

IMPORTANT: A wire should be inserted into drain holes to ensure that foreign material is not obstructing the drain holes.

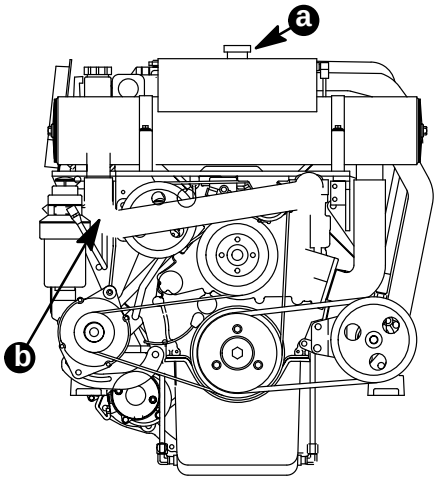
IMPORTANT: Engine must be as level as possible to ensure complete draining of cooling system.

IMPORTANT: Closed cooled section must be kept filled year round with recommended coolant. If engine will be exposed to freezing temperatures, make sure closed cooled section is filled with an ethylene glycol antifreeze and water solution properly mixed to protect engine to lowest temperature to which it will be exposed.

IMPORTANT: Do not use Propylene Glycol Antifreeze in the closed cooled section of the engine.

NOTE: *Drain coolant into a suitable container. Dispose of old coolant properly.*

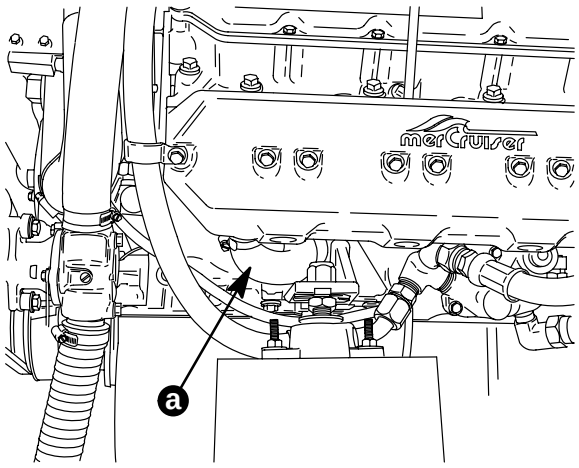
1. After engine cools down, remove pressure cap from coolant tank.
2. Disconnect hose from bottom of the heat exchanger.



76186

a - Pressure Cap
b - Hose

3. Remove the engine block-to-manifold hoses (port and starboard) and drain.

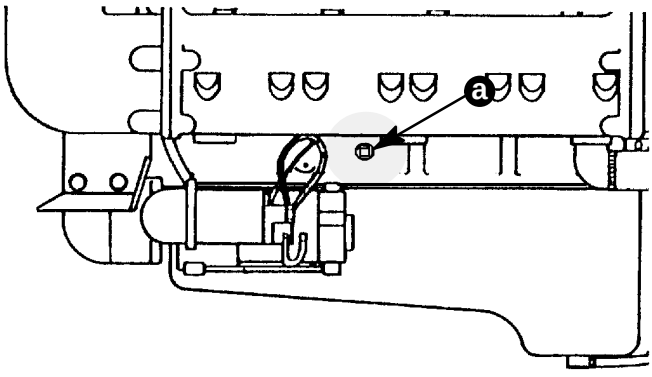


76113

Port Manifold Shown (Starboard Similar)

a - Exhaust Manifold
b - Hose

4. Remove port and starboard drain plugs from from the cylinder block and allow coolant to drain.



73255

Starboard Shown (Port Similar)

a - Crankcase Drain Plug (Below Manifold - Both Sides of Engine)

5. After coolant has drained completely, coat threads of drain plugs with Quicksilver Perfect Seal and reinstall. Tighten securely.
6. Reinstall exhaust manifold hoses. Tighten clamps securely.
7. Remove coolant recovery bottle from mounting bracket and pour out coolant.
8. Fill system as outlined in “Filling Closed Cooling Section.”

Filling Closed Cooling Section

1. Remove pressure cap from heat exchanger and fill section with Quicksilver Premixed Marine Engine Coolant through heat exchanger fill neck. Continue filling until coolant level is 1 in. (25 mm) below filler neck.

⚠ CAUTION

Avoid seawater pickup pump impeller damage and subsequent overheating damage to stern drive unit. DO NOT operate engine without water being supplied to seawater pickup pump.

2. With pressure cap off, start engine and run at fast idle (1500-1800 RPM). Add coolant solution to heat exchanger, as required, to maintain coolant level 1 in. (25 mm) below filler neck.
3. After engine has reached normal operating temperature (thermostat is fully open), and coolant level remains constant, fill heat exchanger to bottom of filler neck.
4. Observe engine temperature gauge to make sure that engine operating temperature is normal. If gauge indicates excessive temperature, stop engine immediately and examine for cause.
5. Install pressure cap on heat exchanger.
6. Remove cap from coolant recovery reservoir and fill to FULL mark with coolant solution. Reinstall cap.
7. With engine still running, check hose connections, fittings and gaskets for leaks. Repeat Step 4.

Flushing Seawater Cooling System

If engine is operated in salty, polluted or mineral-laden waters, seawater cooled section should be flushed periodically (preferably after each use) with fresh water to reduce corrosion and prevent the accumulation of deposits in the system. Seawater cooled section also should be thoroughly flushed prior to storage.

NOTE: *The closed section of cooling system that contains coolant does not need to be flushed. Coolant is changed at specified intervals. Refer to "Maintenance Chart."*

⚠ WARNING

When flushing, be certain the area around propeller is clear, and no one is standing nearby. To avoid possible injury, remove propeller.

⚠ CAUTION

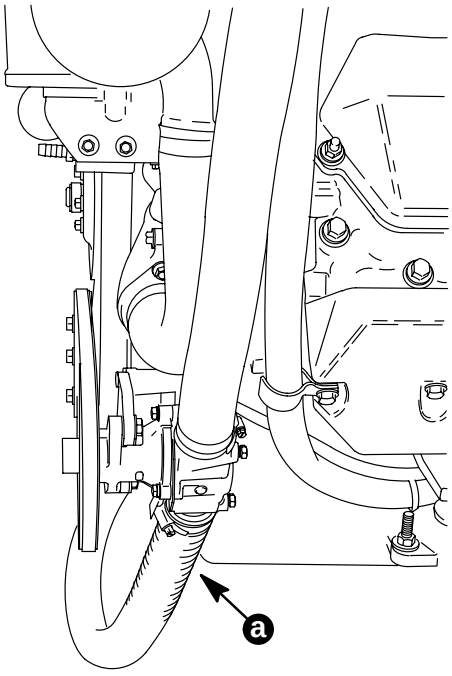
Do not run engine above 1500 RPM when flushing. Suction created by seawater pickup pump may collapse flushing hose, causing engine to overheat.

IMPORTANT: If cooling system is to be flushed with boat in the water, seacock (if so equipped) must be closed, or water inlet hose must be disconnected and plugged to prevent water from flowing into boat.

⚠ CAUTION

Watch temperature gauge at dash to ensure the engine does not overheat.

1. Close seacock (if so equipped) or remove and plug seawater inlet hose.
2. Loosen hose clamp and remove seawater inlet hose at location shown. Connect tap water hose to inlet fitting.



76107

a - Seawater Inlet Hose

3. Place remote control in NEUTRAL, idle speed position and start engine. Operate engine at idle speed, in NEUTRAL, for about 10 minutes, or until discharge water is clear.
4. Stop engine.

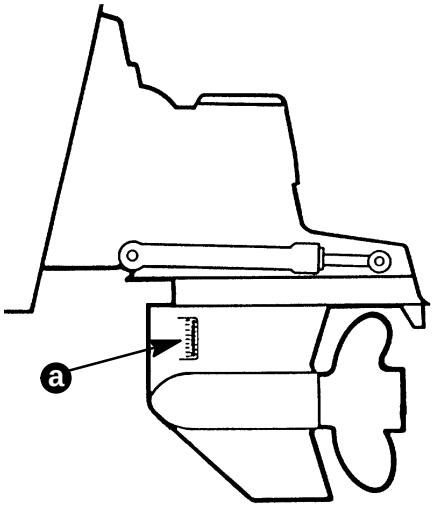
⚠CAUTION

If boat is in the water, seacock (if so equipped) must be left closed until engine is to be restarted, to prevent water from flowing back into cooling system. If boat is not fitted with a seacock, water inlet hose must be left disconnected and plugged, to prevent water from flowing into cooling system and/or boat. As a precautionary measure, attach a tag to the ignition switch or steering wheel with the warning that the seacock must be opened or the water inlet hose reconnected prior to starting the engine.

5. Shut off tap water. Remove flushing connector at seawater pump inlet. Refer to preceding precautionary statement and then follow instructions “a” or “b.”
   a. **If equipped with seacock:** Reconnect water inlet hose and tighten hose clamp securely. Open seacock accordingly.
   b. **If NOT equipped with seacock:** Unplug and reconnect seawater inlet hose accordingly. Tighten hose clamp securely.

Inspect Water Pickups

Check water inlet area of gear housing to ensure that openings are clean and not obstructed.



73186

a - Water Inlet Holes

Check/Clean Seawater Strainer

1. Visually inspect seawater strainer through glass top.

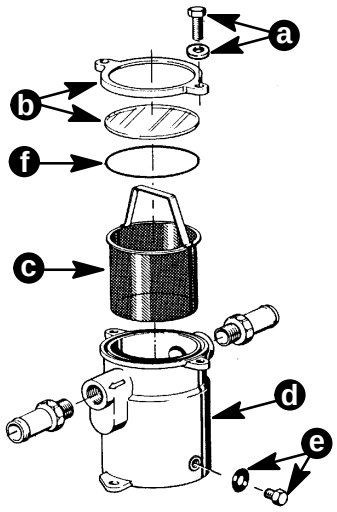
⚠CAUTION

When cleaning seawater strainer, close seacock, if so equipped. If boat is not equipped with a seacock, remove and plug seawater inlet hose to prevent a siphoning action that may occur, allowing seawater to flow from the drain holes or removed hoses.

⚠CAUTION

Do not overtighten cover screws or cover will warp and leak.

2. With engine off, close seacock (if so equipped) or remove and plug seawater inlet hose if no seacock exists. Remove two screws, washers, and cover. Remove strainer, drain plug and washer. Clean all debris from strainer housing; flush both strainer and housing with clean water. Check gasket and replace when necessary (if it leaks). Reinstall strainer, drain plug and washer. Reattach cover with screws and washers. After starting engine, check for leaks and/or air in system, which would indicate an external leak.



72673

a - Screws and Washers
b - Cover, with Glass
c - Strainer
d - Housing
e - Drain Plug and Sealing Washer
f - Gasket

Fuel Filter

⚠WARNING

Always disconnect battery cables from battery BEFORE working on fuel system to prevent fire. This eliminates the engine wiring as a potential source of ignition.

⚠CAUTION

Absolute cleanliness is required for work on the fuel injection system, since the injection pump and fuel injectors have very close tolerances. Even minute particles of dirt or small amounts of water can impair the function of the fuel injection system.

⚠WARNING

Be careful when draining, filling or replacing water separating fuel filter; diesel fuel is flammable. Be sure that the ignition key is OFF. DO NOT smoke or allow sources of open flame in the area while changing fuel system components. Wipe up any spilled fuel immediately. DO NOT allow fuel to come into contact with any hot surface which may cause it to ignite.

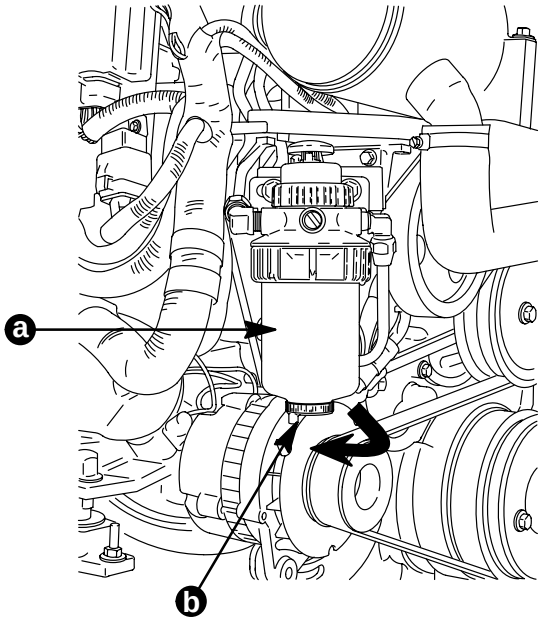
Draining

⚠WARNING

Dispose of fuel-soaked rags, paper, etc., in an appropriate air tight, fire retardant container. Fuel-soaked items may spontaneously ignite and result in a fire hazard which could cause serious bodily injury or death.

NOTE: *In warm weather, open the drain cock before starting daily operations. In cold weather, when there is a possibility that the condensed water will freeze, drain the filter shortly after the end of daily operations.*

1. Open the drain cock at bottom of filter by turning the drain counterclockwise (*as viewed from the bottom of the filter*).



76102

a - Fuel Filter
b - Drain Cock

2. Drain until fuel is clear in appearance.
3. Close drain cock by turning clockwise (*as viewed from the bottom of the filter*). Tighten securely.
4. Fill fuel filter as outlined later in this section.

⚠WARNING

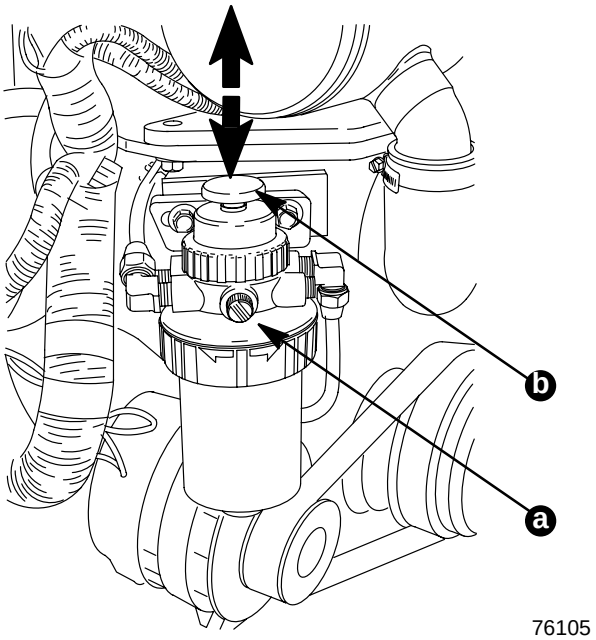
Make sure no fuel leaks exist before closing engine hatch.

Filling

⚠WARNING

Dispose of fuel-soaked rags, paper, etc., in an appropriate air tight, fire retardant container. Fuel-soaked items may spontaneously ignite and result in a fire hazard which could cause serious bodily injury or death.

1. Loosen bleeder valve on fuel filter header flange.
2. Move plunger on hand pump/primer up and down repeatedly, until an air free stream of fuel flows from bleeder valve. Filter is full when this occurs.



76105

a - Bleeder Valve
b - Hand Pump/Primer

3. Retighten bleeder valve.

⚠WARNING

Make sure no fuel leaks exist before closing engine hatch.

Replacing

⚠WARNING

Always disconnect battery cables from battery BEFORE working on fuel system to prevent fire. This eliminates the engine wiring as a potential source of ignition.

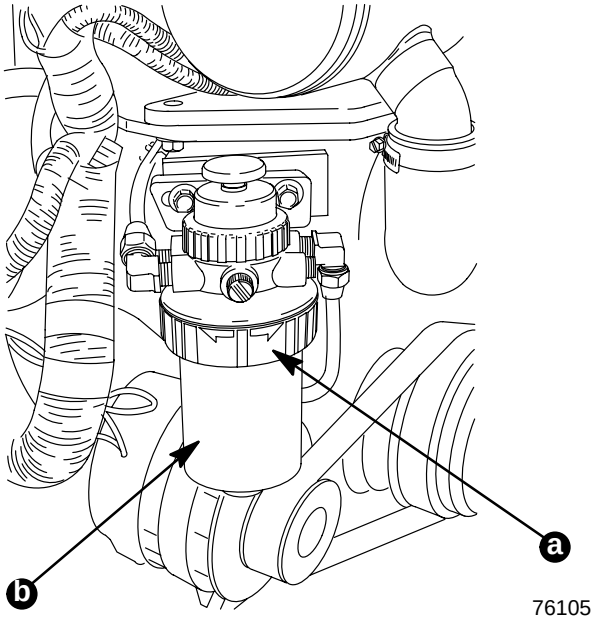
⚠WARNING

Be careful when changing water separating fuel filter; diesel fuel is flammable. Be sure that the ignition key is OFF. DO NOT smoke or allow sources of open flame in the area while changing fuel system components. Wipe up any spilled fuel immediately. DO NOT allow fuel to come into contact with any hot surface which may cause it to ignite.

⚠WARNING

Dispose of fuel-soaked rags, paper, etc., in an appropriate air tight, fire retardant container. Fuel-soaked items may spontaneously ignite and result in a fire hazard which could cause serious bodily injury or death.

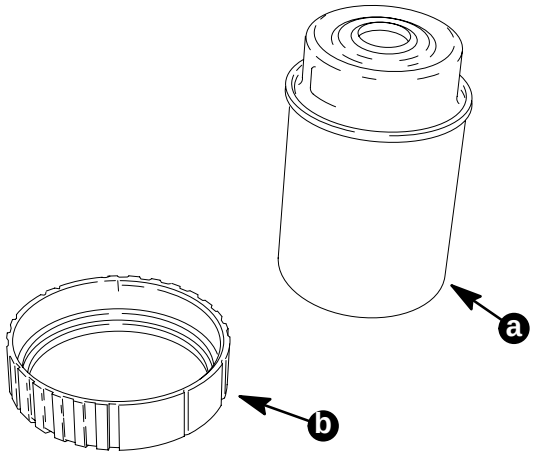
1. Remove filter retaining ring.



76105

a - Retaining Ring
b - Filter

2. Pull down on filter to remove it.
3. Clean filter sealing surface on fuel filter adapter.
4. Install new gasket.
5. Install new filter and secure with retaining ring.



76114

a - Filter
b - Retaining Ring

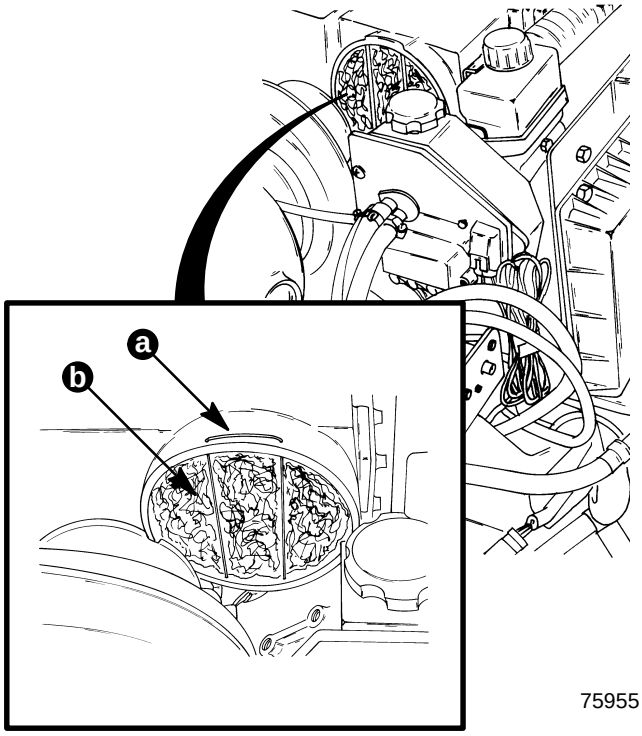
6. Fill fuel filter as outlined previously.
7. Start and run engine. Check filter connections for fuel leaks. If leaks exist, recheck filter installation and correct as needed.

⚠WARNING

Make sure no fuel leaks exist before closing engine hatch.

Clean/Replace Air Filter

1. Remove wire retainer that secures air cleaner element.



75955

a - Wirer Retainer
b - Filter Element

2. Carefully remove air cleaner element from around air intake screen housing mounted on the aftercooler air inlet.

3. Inspect element for tears or holes.

IMPORTANT: Replace the element if it is deteriorated or torn. (Refer to MAINTENANCE - "Maintenance Schedules" for replacement interval under normal conditions.)

4. Wash element in warm water and detergent until clean.

IMPORTANT: No treatment (such as partial oil saturation) is required or recommended on air cleaner element prior to use. Use element clean and dry for proper filtration.

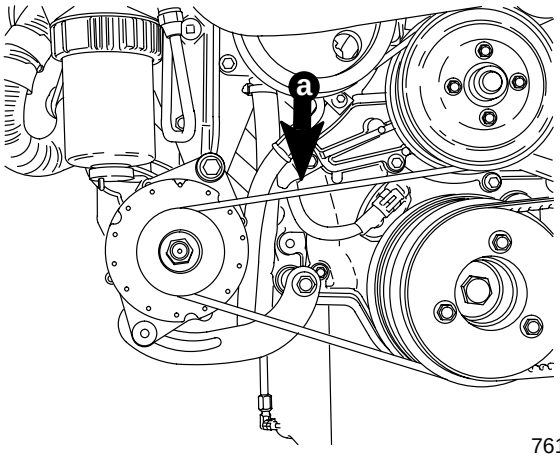
5. Allow element to completely dry before use and install around air intake screen.
6. Inspect installation to ensure engine draws in filtered air only.

Inspect Drive Belts

⚠ WARNING

Make sure engine is stopped and ignition key is removed.

1. Visually inspect all drive belts for cracks, glazing, fraying or separation.
2. Check drive belts for proper tension by pressing at center point between pulleys. Belt(s) must not deflect more than 3/16 in. (5 mm).



76117

a - Drive Belt

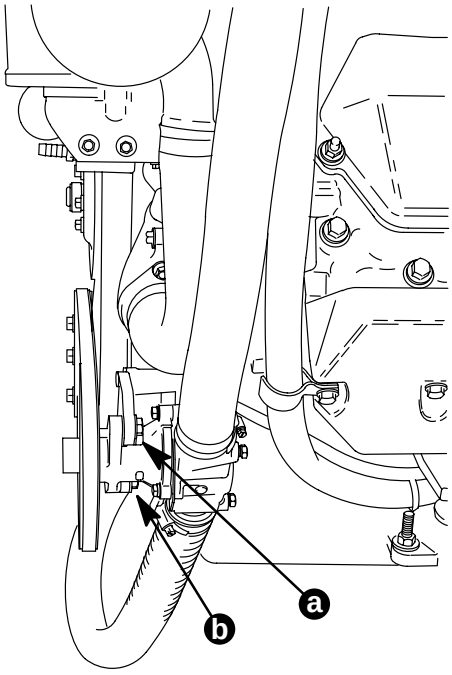
Replace Drive Belts

Belt and Pulley Replacement Guidelines:

- Do not use belt dressing.
- Always check condition of remaining belts. Replace belt if worn, cracked, grease- or oil-soaked.
- When replacing belt and pulley, pulley alignment must be checked under tensioned condition (brackets securely clamped). A misalignment that can be detected by visual inspection is detrimental to belt performance.
- If belt is disturbed for any reason, it must be tensioned to the correct tension.
- Replace pulleys if worn, or clean if still suitable for service.

SEAWATER PUMP BELT

1. Loosen mounting bolt on seawater pump.
2. Loosen tensioning bolt on seawater pump.



76107

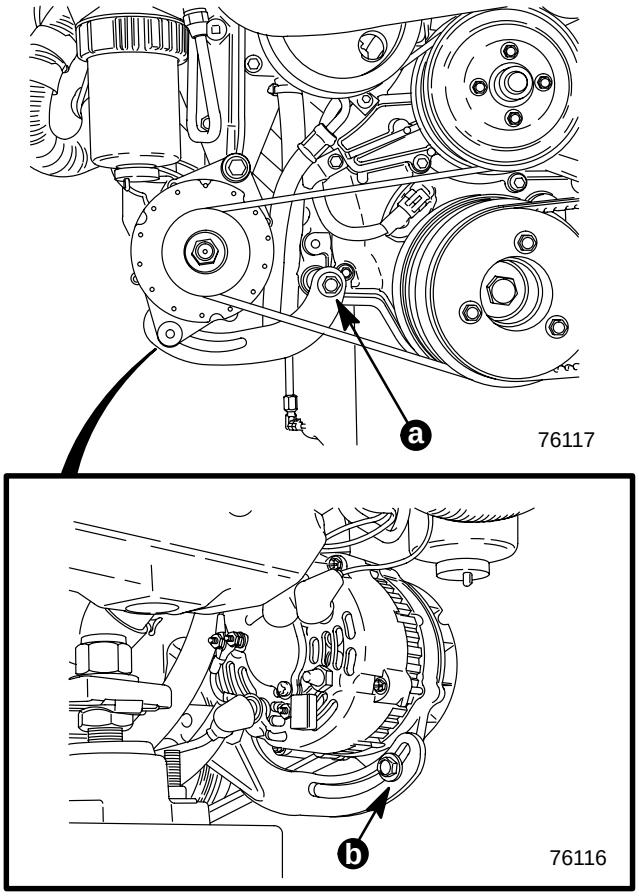
a - Seawater Pump Mounting Bolt
b - Seawater Pump Tensioning Bolt

3. Move or pry seawater pump to loosen belt.
4. Remove seawater pump belt.
5. Install new seawater pump belt.
6. Move or pry seawater pump to adjust belt. Tighten tensioning bolt and mounting bolt on seawater pump securely.

7. Check belt tension. Approximately 3/16 in. (5 mm) deflection should be measured at midpoint between the pulleys on the longest span. Refer to “Inspect Drive Belts” as previously outlined.

ALTERNATOR BELT

1. Remove seawater pump belt.
2. Loosen alternator mounting hardware.



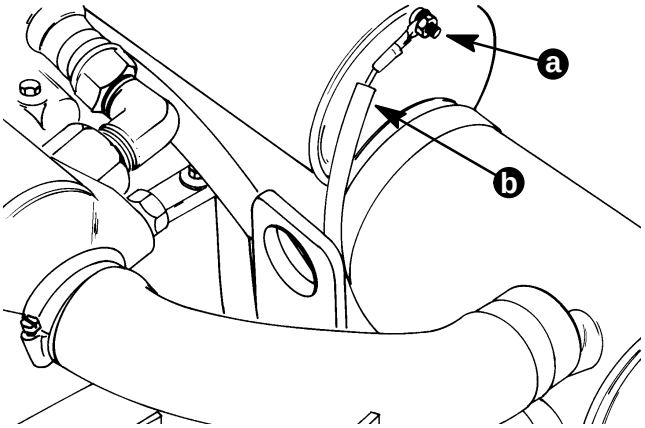
a - Alternator Mounting Hardware
b - Alternator Tensioning Bolt

3. Loosen alternator tensioning bolt.
4. Move or pry alternator to loosen belt.
5. Remove alternator belt.
6. Install new alternator belt.
7. Move or pry alternator to adjust belt. Tighten tensioning bolt and mounting bolt securely.
8. Check belt tension. Approximately 3/16 in. (5 mm) deflection should be measured at midpoint between the pulleys on the longest span. Refer to “Inspect Drive Belts” as previously outlined.
9. Reinstall seawater pump belt.

Inspect/Replace Cooling System Sacrificial Anodes

COOLANT TANK / HEAT EXCHANGER GROUND CIRCUIT

On the top starboard side of the heat exchanger a stud is provided with a wire connection made to the ground stud on the alternator. Inspect the BLACK wire for a loose connection, or if it is broken or frayed. Repair as needed.

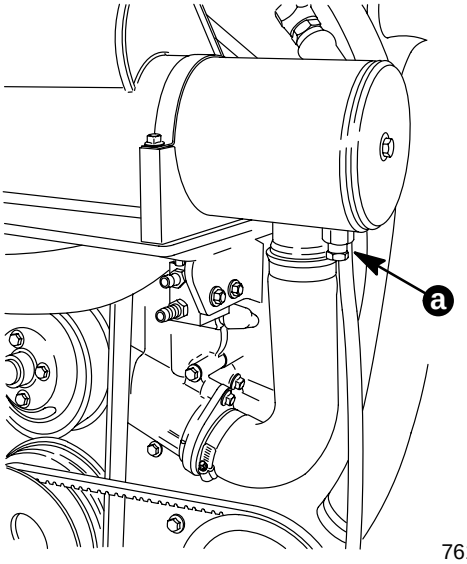


a - Heat Exchanger Ground Circuit Stud
b - BLACK Wire Connection to Alternator Ground Stud

Coolant Tank / Heat Exchanger Anode

INSPECTION

The sacrificial anode is located at the bottom port side of the heat exchanger.

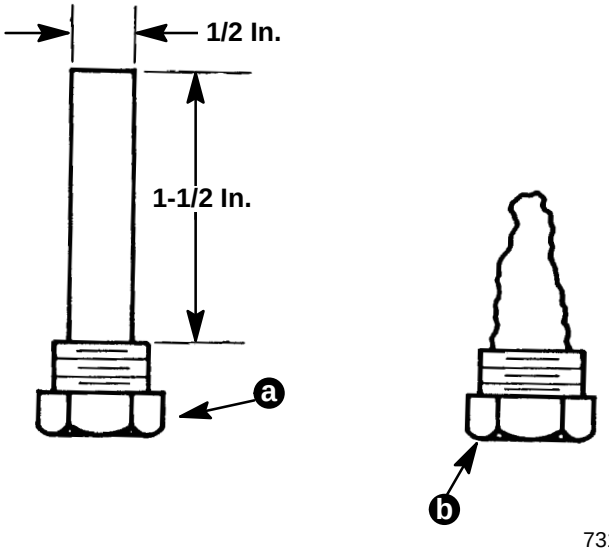


76108

a - Hose - To Circulating Pump

REPLACEMENT

1. With the engine cold, remove sacrificial anode and inspect for deterioration.
2. Replace anode assembly when deteriorated 50%.



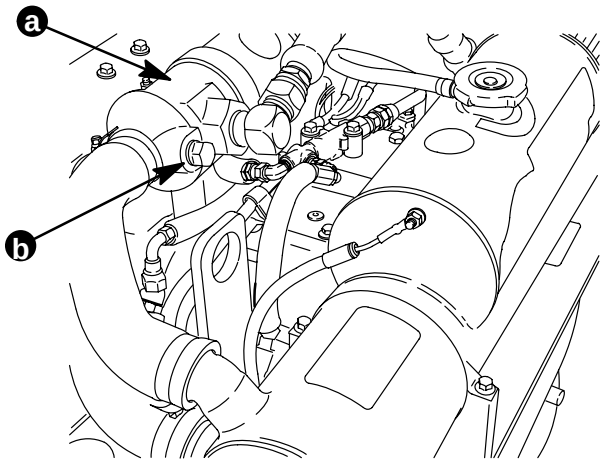
73192

a - New Anode Assembly
b - Example of a Deteriorated Anode

Oil Cooler Anode

INSPECTION

The sacrificial anode is located at the top starboard side of the oil cooler.

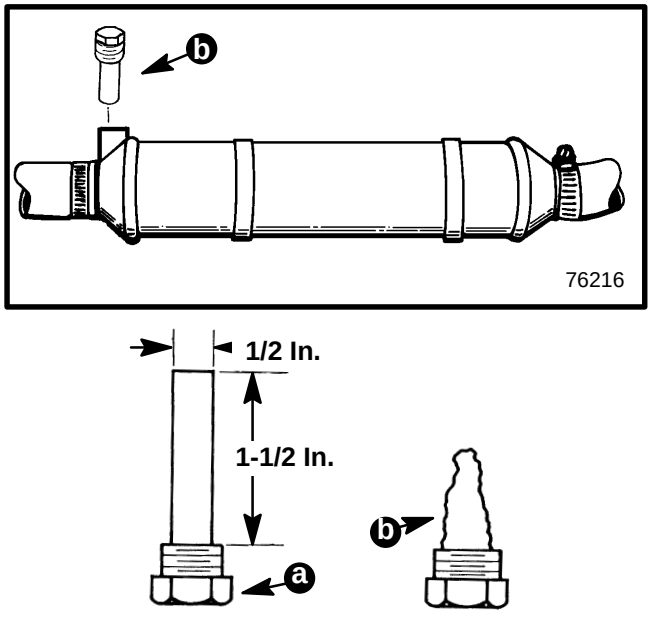


76120

a - Engine Oil Cooler
b - Sacrificial Anode

REPLACEMENT

1. With the engine cold, remove sacrificial anode and inspect for deterioration (Refer to “Inspection” for location, as previously shown.).
2. Replace anode assembly when deteriorated 50%.



a - New Anode Assembly
b - Example of a Deteriorated Anode

Corrosion and Corrosion Protection

1. After first cleaning all surfaces, check all metal surfaces and touch up with Quicksilver Paint as necessary.
2. To maintain a corrosion protective coating on all metal surface areas, spray with Quicksilver Corrosion Guard.

NOTICE

For additional information on Drive Unit corrosion protection and external corrosion protection refer to appropriate Stern Drive Service Manual.

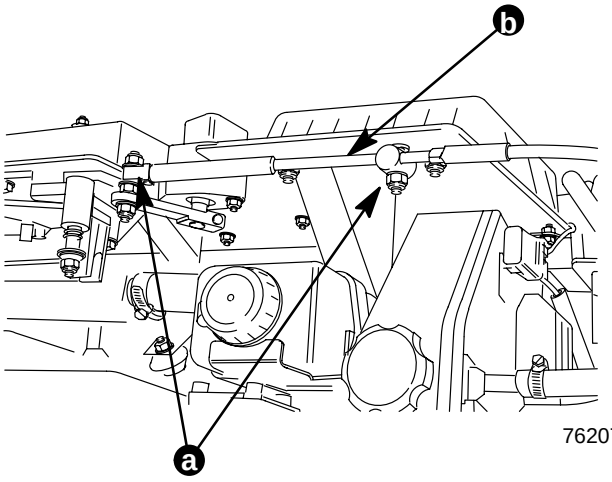
Check Battery

1. Check battery connections to ensure they are clean and tight.
2. Keep exterior surfaces of battery wiped clean with a water/baking soda solution.
3. Ensure battery is securely fastened in place.
4. Refer to battery manufacturer's recommendations for fluid levels and charging.

Lubrication

THROTTLE CABLE

Lubricate pivot points and guide contact surfaces with SAE 30W motor oil.

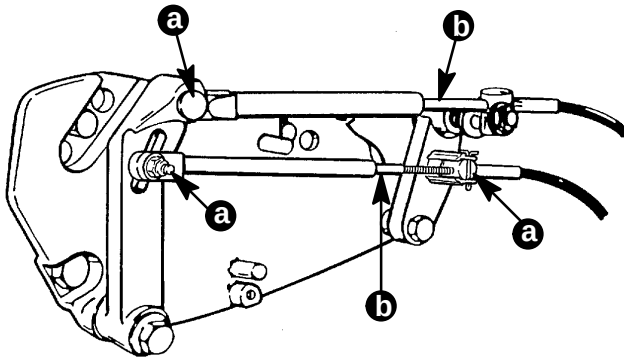


76207

a - Pivot Points
b - Guide Contact Surfaces

SHIFT CABLE

Lubricate pivot points and guide contact surfaces with SAE 30W motor oil.

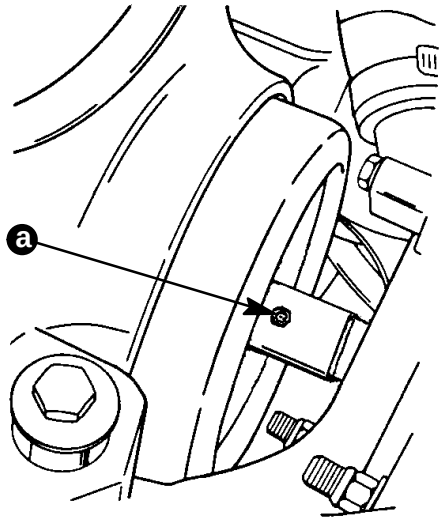


72016

a - Pivot Points
b - Guide Contact Surface

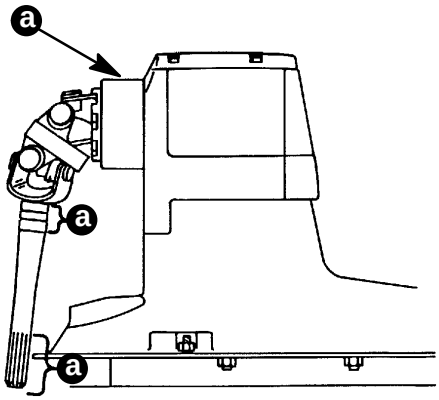
ENGINE COUPLER/U-JOINT SHAFT SPLINES

NOTE: *Refer to MerCruiser Stern Drive Service Manual for stern drive unit removal and installation.*



73346

a - Quicksilver Engine Coupler Spline Grease



72531

a - Quicksilver Engine Coupler Spline Grease

Freezing Temperature and Cold Weather Operation

IMPORTANT: If boat is operated during periods of freezing temperature, precautions must be taken to prevent freezing damage to power package. Refer to the following and to "Cold Weather or Extended Storage" for related information and draining instructions.

In order to operate the engine in temperatures of 32°F (0°C) or lower, observe the following instructions:

⚠CAUTION

Seawater (raw water) section of cooling system MUST BE COMPLETELY drained for winter storage or immediately after cold weather use, if the possibility of freezing temperatures exist. Failure to comply may result in trapped water causing freeze and/or corrosion damage to engine.

1. At the end of each daily operation, COMPLETELY drain seawater section of the cooling system and the seawater strainer to protect against damage by freezing. Refer to Section 6A, and the precautionary statement above.

⚠CAUTION

If boat is in the water, seacock (water inlet valve), if so equipped, must remain closed until engine is to be re-started to prevent water from flowing back into seawater cooling system. If boat is not fitted with a seacock, water inlet hose must be left disconnected and plugged to prevent water from flowing into cooling system and/or boat. As a precautionary measure, attach a tag to the ignition switch or steering wheel with the warning that the valve must be opened or the water inlet hose reconnected prior to starting the engine.

2. At the end of each daily operation, drain water from water separator, if equipped. Fill fuel tank at end of daily operation to prevent condensation.
3. Closed cooling section of engine must be filled with specified coolant or a mixture of antifreeze/water solution sufficient to prevent freezing to the coldest temperature of the user area.
4. Be sure to use proper cold weather lubrication oil, and be sure the crankcase contains a sufficient amount.

5. Make certain that the battery is of sufficient size and is fully charged. Check that all other electrical equipment is in optimum condition.
6. At temperatures of –4°F (–20 C) and below, it is recommended that you use the crankcase mounted coolant heater to improve cold starting.
7. If operating in arctic temperatures of –20°F (–29°C) or lower, consult your dealer for information about special cold weather equipment and precautions.

Saltwater Operation

Seawater section must be flushed after each use. Refer to “Flushing Seawater Cooling System”.

Cold Weather or Extended Storage

PRECAUTIONS

⚠CAUTION

Seawater section of cooling system MUST BE COMPLETELY drained for winter storage, or immediately after cold weather use, if the possibility of freezing temperatures exists. Failure to comply may result in trapped water causing freeze and/or corrosion damage to engine.

⚠CAUTION

If boat is in the water, seacock (water inlet valve), if so equipped, must remain closed until engine is to be re-started, to prevent water from flowing back into cooling system and/or boat. If boat is not fitted with a seacock, water inlet hose must remain disconnected and plugged (to prevent water from flowing back into cooling system and/or boat). As a precautionary measure, attach a tag to the ignition switch or steering wheel of the boat with the warning: Open seacock or reconnect water inlet hose before starting engine.

IMPORTANT: Observe the following information to ensure complete draining of cooling system.

- **Engine must be as level as possible.**
- **A wire should be repeatedly inserted into all drain holes to ensure there are no obstructions in passages. Remove petcock, if necessary, to insert wire completely into drain hole.**

IMPORTANT: To prevent threads in cylinder blocks from rusting out during storage, reinstall plugs using Quicksilver Perfect Seal on threads. Never leave drain plugs out during storage.

NOTE: *If possible, place a container under drains and hoses to prevent water from draining into boat.*

⚠CAUTION

Closed cooling section of engine must be kept filled with specified coolant to protect engine to lowest temperature to which it will be exposed. DO NOT USE PROPYLENE GLYCOL antifreeze in closed cooling section. Seawater section, however, must be drained completely.

⚠CAUTION

A discharged battery can be damaged by freezing.

Layup

NOTICE

Refer to “Cold Weather or Extended Storage,” “Precautions,” in this section, BEFORE proceeding.

IMPORTANT: This service should be performed by an authorized MerCruiser dealer.

⚠CAUTION

The engine must be prepared for long storage periods to prevent internal corrosion and severe damage.

⚠WARNING

Do not remove coolant cap when engine is hot; coolant may discharge violently causing severe burns.

1. Slowly and carefully remove coolant tank cap from the heat exchanger. Be certain coolant level is to the bottom of the filler opening. If not, add specified coolant as necessary to achieve proper level.

IMPORTANT: If boat has already been removed from water, before starting engine a source of water must be supplied to water intake (inlet) openings. Follow all warnings and flushing attachment procedures stated in "Flushing Seawater Cooling System."

⚠ CAUTION

DO NOT operate engine without cooling water being supplied to seawater pickup pump or water pump impeller will be damaged and subsequent overheating damage to engine may result.

2. Start engine and run until it reaches normal operating temperature. Stop engine.
3. Change crankcase oil and oil filter (refer to "Changing Crankcase Oil and Oil Filter"). Be certain to fill engine with correct amount of recommended oil. Always use dipstick to determine exact amount of oil required.
4. Start engine and run at IDLE for about 15 minutes. Check for any oil leaks and correct as necessary.
5. Drain seawater section of cooling system and prepare for cold weather or extended storage following these procedures:

IMPORTANT: Drain only the seawater section of the cooling system.

IMPORTANT: Closed cooling section must be kept filled year-round with specified coolant.

DRAINING INSTRUCTIONS

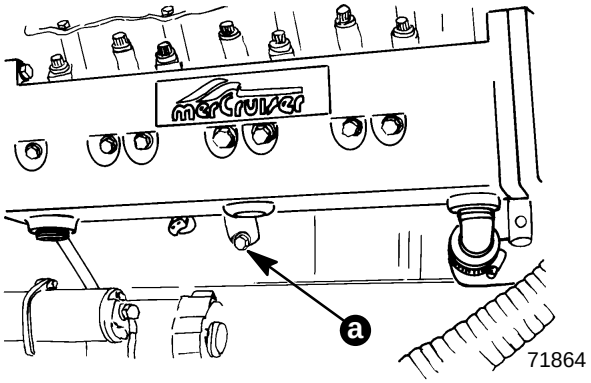
⚠ CAUTION

If boat is to remain in the water, seacock, if so equipped, must be closed until engine is to be restarted to prevent water from flowing back into seawater cooling system. If boat is not fitted with a seacock, water inlet hose must be disconnected and plugged to prevent water from flowing into cooling system and/or boat. As a precautionary measure, attach a tag to the ignition switch or steering wheel with the warning that the valve must be opened or the water inlet hose reconnected prior to starting the engine.

IMPORTANT: Observe the following information to ensure complete draining of seawater cooling system.

- **Engine must be as level as possible.**
- **A wire should be repeatedly inserted into all drain holes to ensure there are no obstructions in passages.**

1. Close seacock, if so equipped, or disconnect and plug seawater inlet hose, if boat is to remain in the water.
2. Do not remove either of the two drain plugs on the cylinder block [one port and one starboard]. **They are in the closed cooling section.**

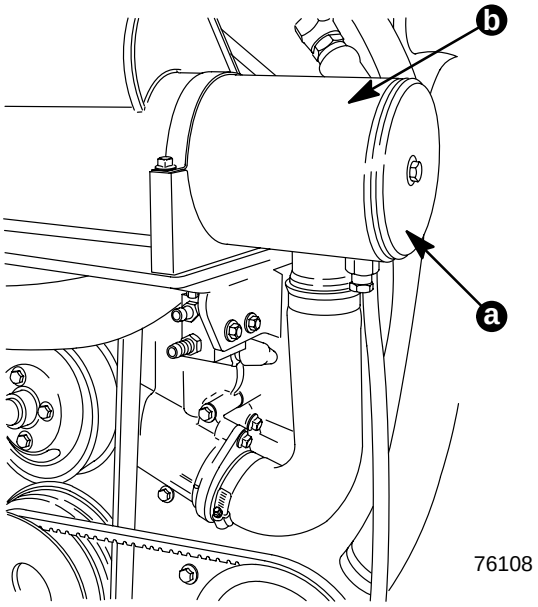


a - Crankcase Drain Plugs (Both Sides of Engine -Do Not Remove)

3. Remove the following:

IMPORTANT: A wire should be repeatedly inserted into drain holes to ensure that foreign material is not obstructing the drain holes.

a. Remove the end covers from both the port and starboard sides of heat exchanger. Drain tank completely.



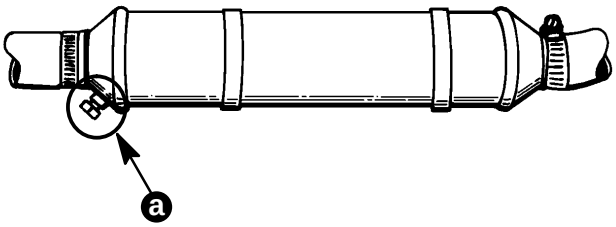
76108

Port Side Shown (Starboard Similar)

a - End Cover
b - Coolant Tank / Heat Exchanger

IMPORTANT: Use compressed air to blow any remaining water from the tubes in the heat exchanger.

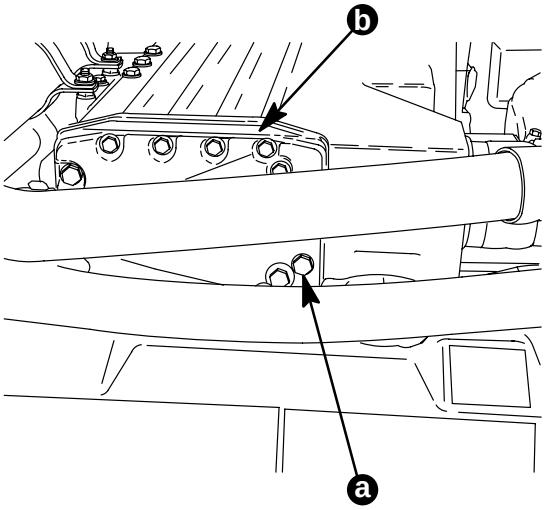
b. The drain plug on the lower side of the engine oil cooler.



71870

a - Engine Oil Cooler Drain Plug

c. The aftercooler drain plugs located on the starboard and port aftercooler side covers.



76122

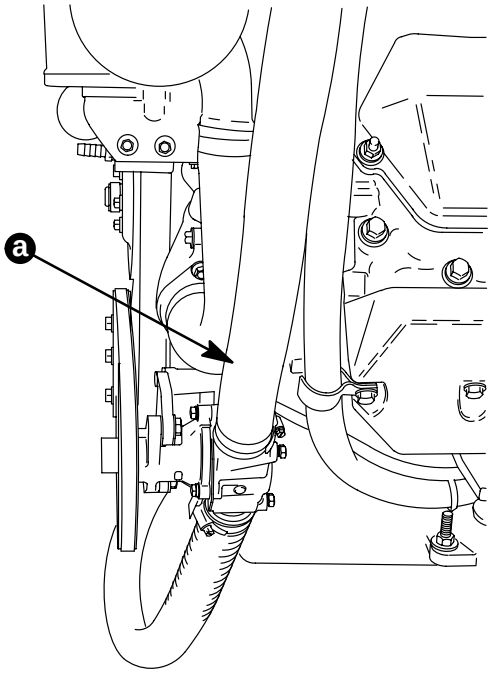
Port Side Shown (Starboard Similar)

a - Aftercooler Drain Plugs
b - Aftercooler Side Cover

4. Repeatedly clean out drain holes using a stiff piece of wire. Do this until entire system is drained.

NOTE: *It may be necessary to lift or bend hoses to allow water to drain completely.*

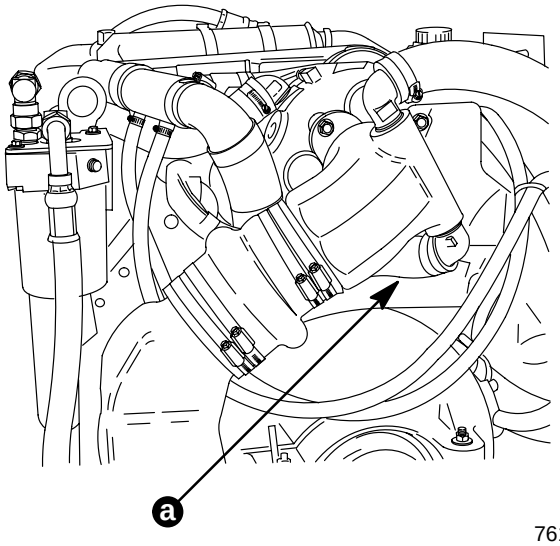
5. Remove seawater pump outlet hose from top of seawater pump and drain.



76107

a - Seawater Pump Outlet Hose

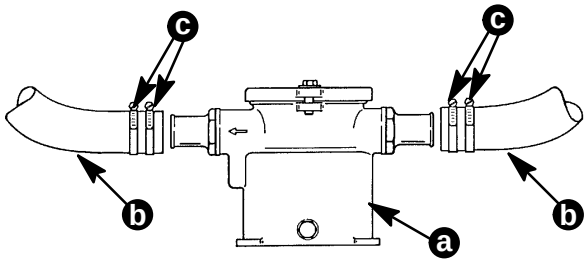
6. Disconnect seawater hose at bottom of exhaust elbow. Lower hose and drain completely.



76106

a - Seawater Hose Connected To Exhaust Elbow

7. Remove hose(s) at seawater strainer and drain hose (s) completely. Empty saewater stainer. Reconnect hose(s) and tighten hose clamp securely.



72691

a - Seawater Strainer
b - Hoses
c - Hose Clamps

8. Make sure that sterndrive unit pitot tube, trim tab cavity vent hole, and trim tab cavity drain passage are unobstructed and open.

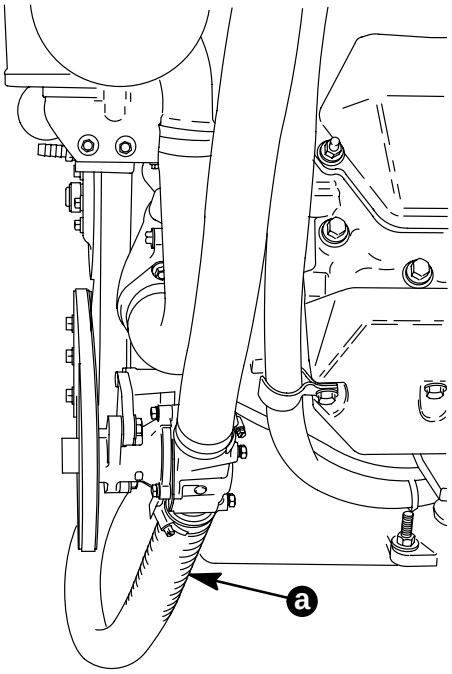
9. After seawater section of cooling system has been drained completely, coat threads of drain plugs with Perfect Seal and reinstall. Tighten securely. Reconnect hoses. Tighten hose clamps securely. Replace end cover gaskets and seals if worn or deteriorated. Install end cover assemblies on the heat exchanger. Torque the end covers to 120-132 lb. in. (14-15 N·m).

10. After seawater section of cooling system has drained completely, coat threads of drain plugs previously removed with Quicksilver Perfect Seal, and reinstall. Tighten securely. Install all hoses previously removed and tighten hose clamps securely.

IMPORTANT: MerCruiser recommends that propylene glycol antifreeze (nontoxic and biodegradable, which makes it friendly to lakes and rivers) be used in seawater section of the cooling system for cold weather or extended storage. Make sure that the propylene glycol antifreeze contains a rust inhibitor and is recommended for use in marine engines. Be certain to follow the propylene glycol manufacturer's recommendations.

11. Fill a container with approximately 6 U.S. quarts (5.6 L) of antifreeze and tap water mixed to manufacturer's recommendation to protect engine to the lowest temperature to which it will be exposed during cold weather or extended storage.

12. Disconnect hose from seawater inlet side of seawater pump. Using an adaptor, temporarily connect an appropriate length piece of hose to seawater pump and place the other end of the hose into container of coolant.

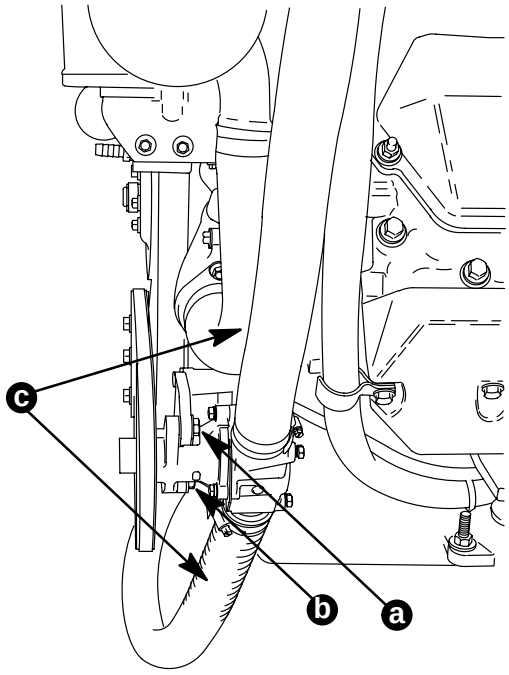


a - Seawater Pump Inlet Hose

⚠ CAUTION

It is good practice to ventilate the engine compartment prior to servicing any engine components to remove any fuel vapors which may cause difficulty breathing or be an irritant.

13. Start engine and run, AT IDLE SPEED, until antifreeze mixture has been pumped into engine seawater cooling system. Stop engine.
14. Clean engine and coat with Quicksilver Corrosion Guard or equivalent corrosion inhibiting oil.
15. Lubricate all items outlined in “Lubrication”.
16. Remove and store battery in a cool, dry place. Do not store on a concrete surface, or on the ground. Place on a dry, wood board or a thick plastic base (Refer to battery manufacturer’s instructions.)
17. Perform all checks, inspections, lubrication and fluid changes outlined in “Maintenance Schedule” under “At Least Once Yearly”.
18. Remove seawater pump and components as follows:
    a. Disconnect seawater pump hoses.
    b. Remove seawater pump mounting bolt and tensioning bolt. Remove seawater pump.

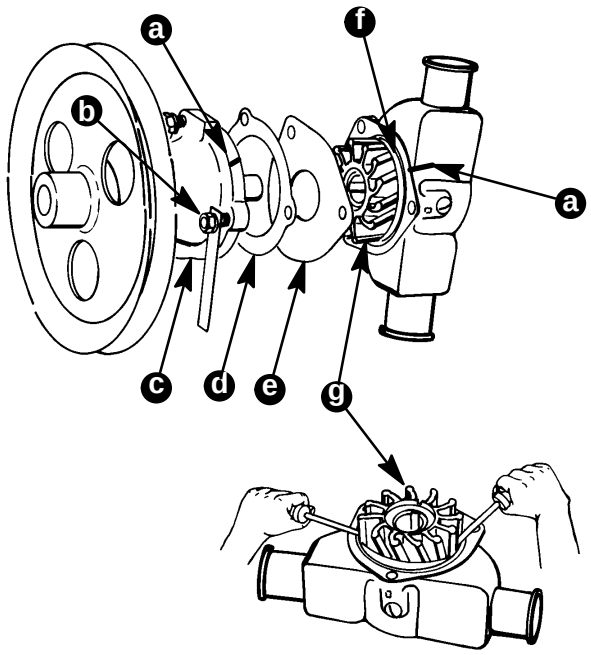


a - Mounting Bolt
b - Tensioning Bolt
c - Seawater Hoses

c. Make matching marks on pump cover and pump housing prior to disassembly (to aid in reassembly later). Remove the three seawater pump cover mounting screws. Remove cover (with pulley and shaft), gasket, and plate.

d. Take notice of O-ring, and location of O-ring in groove on housing.

e. Ease impeller out of pump body with two screwdrivers. Be careful not to damage pump impeller.



a - Matching Marks
b - Cover Screws
c - Cover
d - Gasket
e - Plate
f - O-Ring
g - Impeller

f. Reassemble the components, except for the impeller, for storage.

IMPORTANT: Place a CAUTION TAG at instrument panel and in engine compartment stating that "Seawater Pump is Out - DO NOT Operate Engine."

BATTERY WINTER STORAGE

Follow battery manufacturer's instructions for storage. If not available, use the following instructions:

1. Be certain all electrical components are off, and ignition key is in OFF position.
2. To avoid possible electrical system damage, FIRST remove the NEGATIVE (–) battery cable, and NEXT remove the POSITIVE (+) battery cable. Remove the battery.
3. Remove dirt and grease from top surface of battery.
4. Follow battery manufacturer's recommendations and add distilled water, if needed.
5. Grease cable ends and bolts.
6. Store battery in a cool, dry place. Do not store on a concrete surface, or on the ground. Place on a dry wood board or a thick plastic base.

⚠CAUTION

A discharged battery can be damaged by freezing.

7. Every 30 to 45 days, check water level and recharge battery according to manufacturer's specifications. Do not fast charge.

If you cannot perform the above service, contact your authorized MerCruiser dealer or local automotive garage.

Recommissioning

NOTICE

Refer to "Cold Weather or Extended Storage," "Precautions," in this section, BEFORE proceeding.

1. Reinstall seawater pump components and pump as follows:

NOTE: *Use new gasket and O-ring. Install in correct position.*

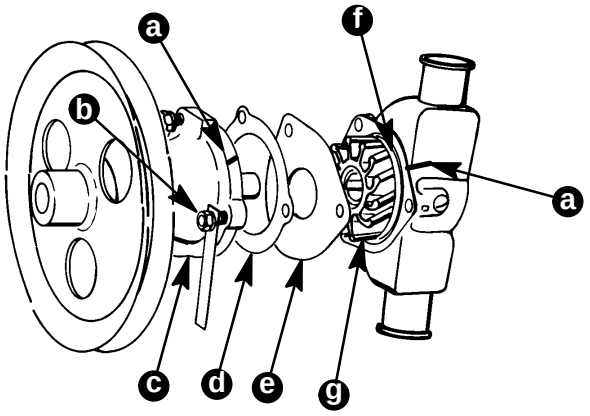
   a. Place impeller in pump housing.

   b. Install new O-ring in groove on housing.

   c. Install pump plate, with new gasket in position.

   d. Engage pump shaft key in impeller keyway and install seawater pump cover. Align matching marks made prior to disassembly.

   e. Install the three seawater pump cover mounting screws. Tighten securely.

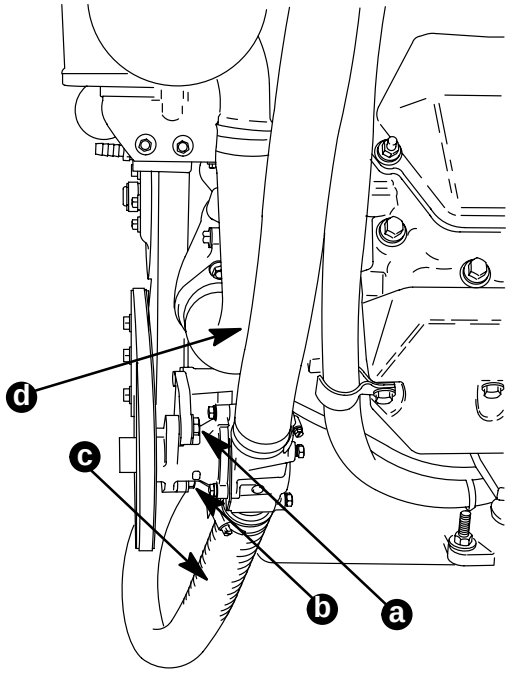


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a - Matching Marks
b - Cover Screws
c - Cover
d - Gasket
e - Plate
f - O-Ring
g - Impeller

   f. Install pump on engine using mounting bolt and tensioning bolt with hardware. Tension drive belt. Tighten fasteners securely.

   g. Connect seawater hoses.



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a - Mounting Bolt
b - Tensioning Bolt
c - Seawater Inlet Hose
d - Seawater Outlet Hose

2. Check that all cooling system hoses are in good condition and connected properly, hose clamps are tight, and all petcocks and drain plugs are installed and tight.

3. Inspect all drive belts.

4. Perform all lubrication and maintenance specified for completion "At Least Once Yearly" in "Maintenance Schedule," except items which were performed at time of engine layup.

5. Fill fuel tank(s) with fresh diesel fuel. Old fuel should not be used. Check fuel lines and connections for leaks and general condition.

6. Replace fuel filter as outlined previously in this section.

7. For drive unit, refer to appropriate Stern Drive Service Manual.

⚠ CAUTION

When installing battery, be sure to connect POSITIVE (+) battery cable to POSITIVE (+) battery terminal FIRST, and NEGATIVE (–) battery cable to NEGATIVE (–) battery terminal LAST. If battery cables are reversed, or connection order is reversed, electrical system damage will result.

8. Install fully charged battery. Clean battery cable clamps and terminals to help retard corrosion.
9. Perform all checks on OPERATION CHART in the STARTING PROCEDURE column in Operation and Maintenance Manual.

IMPORTANT: Avoid starter motor overheating. DO NOT engage starter for more than 15 seconds; allow at least one minute cool-down time before re-engaging starter for another 15 seconds.

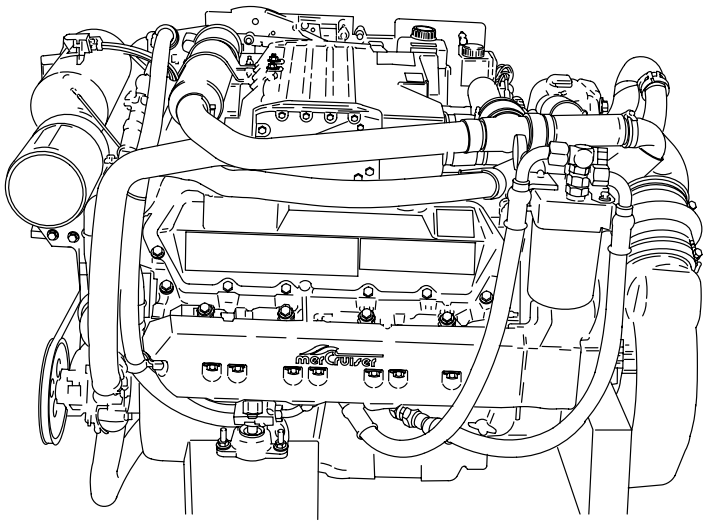
⚠ CAUTION

DO NOT operate engine without water flowing thru seawater pickup pump, as pump impeller may be damaged and subsequent overheating damage to engine or transmission may result.

10. Start engine and closely observe instrumentation to make sure that all systems are functioning correctly.
11. Carefully inspect engine for fuel, oil, fluid, water and exhaust leaks.
12. Check steering system, shift and throttle control for proper operation.

IMPORTANT INFORMATION

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TROUBLESHOOTING

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Precautions

⚠WARNING

Always disconnect battery cables from battery BEFORE working on fuel system to prevent fire or explosion.

⚠WARNING

Always disconnect battery cables from battery before working around electrical system components to prevent injury to yourself or damage to electrical system.

⚠WARNING

Be careful when changing fuel system components; diesel fuel is flammable. Be sure that ignition key is OFF. DO NOT smoke or allow sources of spark or flame in the area while changing fuel system components. Wipe up any spilled fuel immediately. DO NOT allow fuel to come into contact with any hot surface which may cause it to ignite.

⚠WARNING

Avoid diesel fuel fire. Improper installation of brass fittings or plugs into fuel filter base can crack casting and/or cause a fuel leak. Follow specific procedure, given in Section 4 of this manual, for all fuel line connections.

Fuel Supply Connections

⚠WARNING

Avoid diesel fuel fire or explosion. Improper installation of brass fittings or plugs into fuel filter base can crack casting and/or cause a fuel leak.

- **Apply #592 Loctite Pipe Sealant with Teflon to threads of brass fitting or plug. DO NOT USE TEFLON TAPE.**
- **Thread brass fitting or plug into fuel filter base until finger tight.**
- **Tighten fitting or plug an additional 1-3/4 to 2-1/4 turns using a wrench. DO NOT OVER-TIGHTEN.**
- **Install fuel line. To prevent over-tightening, hold brass fitting with suitable wrench and tighten fuel line connectors securely.**
- **Check for fuel leaks.**

⚠WARNING

FIRE HAZARD: Fuel leakage from any part of the fuel system can be a fire hazard which can cause serious bodily injury or death. Careful periodic inspection of entire fuel system is mandatory, particularly after storage. All fuel components including fuel tanks, whether plastic, metal or fiberglass, fuel lines, primers, fittings, and fuel filters should be inspected for leakage, softening, hardening, swelling or corrosion. Any sign of leakage or deterioration requires replacement before further engine operation.

⚠WARNING

Dispose of fuel-soaked rags, paper, etc., in an appropriate air tight, fire retardant container. Fuel-soaked items may spontaneously ignite and result in a fire hazard which could cause serious bodily injury or death.

⚠WARNING

Make sure no fuel leaks exist before closing engine hatch.

⚠CAUTION

DO NOT operate engine without water being supplied to seawater pickup pump on engine, or pump impeller may be damaged and subsequent overheating damage to engine may result. Engine may be operated with boat out of water, if instructions for running engine with boat out of water, below, are followed.

⚠WARNING

When running engine with boat out of water, be certain that area in vicinity of propeller is clear and that no person is standing nearby. As a precautionary measure, it is recommended that the propeller be removed.

⚠CAUTION

DO NOT run engine above 1500 RPM, as suction created by seawater pickup pump may collapse water supply hose and cause engine to overheat.

⚠WARNING

Be sure that engine compartment is well ventilated and that no diesel fuel vapors are present to prevent the possibility of a FIRE or EXPLOSION.

⚠WARNING

DO NOT leave helm unattended while performing idle speed adjustment.

⚠WARNING

Safety glasses should be worn while working on fuel injection system. The fuel injection pump will generate pressures in excess of 2000 PSI (13790 kPa). Use caution when removing injectors, injector lines, or bleeding air from injection system.

Poor Boat Performance and/or Poor Maneuverability

Symptom	Cause
1. Bow too low	1. A. Improper drive unit trim angle B. Improper weight distribution C. Boat is underpowered D. Permanent or power hook in boat bottom E. False bottom full of water F. Improperly adjusted trim tabs (after planes)
2. Bow too high	2. A. Improper drive unit trim angle B. Propeller pitch too great C. Dirty boat bottom (marine growth) D. Poor running engine E. Improper weight distribution F. Rocker in boat bottom G. False bottom full of water H. Improperly adjusted trim tabs (after planes)
3. Propeller ventilating	3. A. Drive unit installed too high on transom B. Dirty or rough boat bottom C. Damaged propeller; pitch too small; diameter too small D. Keel located too close to propeller or too deep in the water E. Water pickup or accessories located too close to propeller F. Hook in boat bottom G. Propeller plugged up with weeds

Improper Full Throttle Engine RPM

RPM Too High

Cause	Special Information
1. Propeller	1. Damaged; pitch too low; diameter too small; propeller hub slipping.
2. Boat	2. A. Water pickup or accessories mounted too close to propeller (ventilation) B. Keel located too close to propeller and/or too deep in the water (ventilation). C. Drive installed too high on transom; D. Wrong gear ratio.
3. Operation	3. Unit trimmed out too far.
4. Engine coupler slipping	

RPM Too Low

Symptom	Cause
1. Propeller	1. Damaged; pitch too great; diameter too great
2. Boat	2. A. Dirty or damaged bottom B. Permanent or power hook in bottom C. False bottom full of water D. Drive installed too low
3. Operation	3. Unit trimmed in too far
4. Scan Tool	4. Refer to Section 5 for complete diagnostic procedures.

Engine Cranks Over but Will Not Start or Starts Hard

Important Information

Determine which engine system is causing the problem. To make an engine run, basic components - fuel, glow plugs, compression, and high pressure oil system current are required. If all are present, the engine should run. If any are missing, weak, or arriving at the wrong time, the engine will not run.

Electrical

Cause	Special Information
1. Battery, electrical connections, damaged wiring	1. Discharged or improperly rated battery. Battery cable size improper.
2. Ignition switch	
3. Glow plugs inoperative	
4. CMP Sensor	4. Defective sensor or sensor wiring.

Fuel System

Cause	Special Information
1. Empty fuel tank	
2. Fuel shutoff valve closed (if equipped)	
3. Low grade, stale fuel or water in fuel	
4. Fuel waxing or frozen water separator (cold weather)	
5. Plugged fuel suction line or filter	
6. Air leaks, suction side fuel line or water separator	6. Sucks air into fuel system reducing fuel volume
7. Plugged or pinched fuel line (feed or return)	
8. Fuel tank vent plugged	8. Engine will start initially. After a short time running,engine will stall and will not restart for a period of time. Can verify if it is a vent problem by running engine with filler cap loose. Filler cap will act as a vent.
9. Fuel supply pump	9. Low pump pressure.

Miscellaneous

Cause	Special Information
1. Low grade or stale fuel	
2. Water in fuel	
3. Incorrect starting procedure	3. Refer to Owners Manual.
4. Internal mechanical damage (bent rods, etc.)	
5. Low compression	5. Worn valves, rings, cylinder, or head gasket
6. Valve timing incorrect	6. Timing gears improperly installed or cam slipped in drive gear
7. Restricted or plugged exhaust	

Engine Will Not Crank Over or Starter Inoperative

Cause	Special Information
1. Remote control lever not in neutral position	
2. Battery charge low; damaged wiring; loose electrical connections	
3. Circuit breaker tripped	
4. Blown fuse	
5. Ignition switch	
6. Slave solenoid	
7. Faulty neutral start safety switch	7. Open circuit
8. Starter solenoid	
9. Starter motor	
10. Engine mechanical malfunction	

Glow Plugs Inoperative

Cause	Special Information
1. Battery discharged	
2. Circuit breaker tripped	2. On dash or in electrical box
3. Poor battery connections	
4. Glow plug(s) defective (burned out)	
5. Glow plug relay defective or inoperative	5. Refer to SECTION 5C
6. ECT Sensor inoperative	6. Refer to SECTION 5C
7. Ignition switch inoperative	
8. Broken or disconnected wire in glow plug circuit	
9. Oil level in the reservoir (High pressure oil system)	9. Refer to SECTION 5B
10. Injection control pressure	10. Refer to SECTION 5B

Charging System Inoperative

Cause	Special Information
1. Loose or broken drive belt	
2. Engine RPM too low on initial start	2. Rev engine to 1500 RPM
3. Loose or corroded electrical connections	
4. Faulty battery gauge	4. Best way to test is to replace gauge
5. Battery will not accept charge	5. Low electrolyte or failed battery
6. Faulty alternator or regulator	
7. Refer to Section 4C for complete "Charging System" diagnosis procedures	

Noisy Alternator

Cause	Special Information
1. Loose mounting bolts	
2. Drive belt	2. Worn, frayed, loose
3. Loose drive pulley	
4. Worn or dirty bearings	
5. Faulty diode trio or stator	
6. Faulty armature	6. Rubbing, broken wire

Engine Runs Poorly at Idle

Cause	Special Information
1. Clogged air cleaner	
2. Improper idle fuel mixture adjustment	
3. Plugged fuel suction line or filter	
4. Air leaks: suction side fuel line, water separating fuel filter or loose intake manifold	
5. Water in fuel	5. Refer to SECTION 1B.
6. Low grade or stale fuel	
7. Fuel waxing or frozen water separating fuel filter (cold weather)	
8. Valve timing	8. Cam slipped in drive gear.
9. Restricted or plugged exhaust	
10. Injectors not functioning properly	10. Refer to SECTION 5.
11. Injection timing incorrect	11. Refer to SECTION 5.
12. Low compression	12. Also check for defective (blown) head gasket.
13. Water leaking into cylinders	13. Defective head gasket, exhaust manifold, cracked head or valve seat.
14. Loose or broken engine mounts	
15. EDI system fault	15. Refer to SECTION 5 for complete diagnostic procedures.

Engine Runs Poorly At High RPM

Cause	Special Information
1. Also refer to “Poor Boat Performance”	1. See “Table of Contents”
2. Crankcase overfilled with oil	2. Check oil level with boat at rest in the water.
3. Anti-siphon valve (if equipped)	3. Restricting fuel supply
4. Plugged fuel tank vent	
5. Low fuel supply	
6. Clogged fuel filter	
7. Low grade of fuel or water in the fuel	
8. Obstructed fuel lines	
9. Injectors not functioning properly	9. Refer to SECTION 5B or 5C.
10. Engine overheating	10. Refer to “Engine Overheats” (See “Table of Contents”)
11. Low compression	11. Worn valves, rings, cylinders, etc.
12. Restricted or plugged exhaust	
13. Refer to SECTION 5 for complete diagnostic procedures.	

Poor Fuel Economy

Cause	Special Information
1. Fuel leaks	
2. Operator habits	2. Prolonged idling; slow acceleration; failure to cut back on throttle once boat is on plane; boat over loaded; uneven weight distribution
3. Engine laboring	3. Bent, damaged, or wrong propeller. Water test boat for proper operating RPM at wide open throttle
4. Clogged air cleaner	
5. Engine compartment sealed too tight	5. Not enough air for engine to run properly
6. Boat bottom	6. Dirty (marine growth), hook, rocker
7. Turbocharger malfunction	
8. Improper fuel	
9. Crankcase ventilation system not working	
10. Engine running too hot or too cold	
11. Plugged or restricted exhaust	
12. Engine	12. Low compression
13. Injectors not functioning properly	
14. Injection timing incorrect	
15. Refer to SECTION 5 for complete diagnostic procedures.	

Engine Smoking (Black)

Cause	Special Information
1. Overload	
2. Clogged air cleaner	
3. Excessive fuel delivery	3. Refer to Section 5A
4. Injection timing over-advanced	4. Refer to Section 5B
5. Faulty injector(s)	5. Refer to Section 5C
6. Restricted or plugged exhaust	
7. Insufficient coolant temperature	
8. Excessive idle time (slobber)	
9. Inoperative glow plug system	9. Refer to Section 4B
10. Leaking head gaskets	
11. Worn piston rings	
12. Refer to SECTION 5 for complete diagnostic procedures.	

Engine Smoking (Blue)

Cause	Special Information
1. Insufficient load	1. Check propeller
2. Low fresh water temperature (faulty thermostat)	2. Check temperature of oil and water
3. Oil leakage from turbocharger	3. Check turbocharger
4. Defective Injector O-rings	
5. Worn piston rings	5. Check compression
6. Sticking piston rings	6. Check compression
7. Crankcase overfilled - incorrect dipstick reading	
8. Leaking head gaskets	
9. Refer to SECTION 5 for complete diagnostic procedures.	

Engine Smoking (White)

Cause	Special Information
1. Injection timing incorrect	1. Refer to Section 5B
2. Faulty injector(s)	2. Refer to Section 5C
3. Low compression	
4. Plugged fuel suction line or filter	
5. Air leaks, suction side fuel line or water separating fuel filter	
6. Questionable fuel quality	
7. Restricted fuel return/excessive return line pressure	
8. Leaking head gaskets	
9. Refer to SECTION 5 for complete diagnostic procedures.	

Exhaust Gas Temperature (High)

Cause	Special Information
1. Excessive load	
2. Injection timing incorrect	2. Refer to Section 5B
3. Wrong assembly - timing device - pressure regulating valve	

Exhaust Gas Temperature (Low)

Cause	Special Information
1. Injection timing incorrect	1. Refer to Section 5B
2. Excessive idling time/light loads	
3. Heater system air locked	

Turbocharger

Make certain that troubles are not due to engine components, especially to injection system, before trouble-shooting turbocharger and/or carrying out corrective action on turbocharger.

Cause	Special Information
1. Smoke from exhaust	1. A. Not enough air getting to engine air intake B. Clogged air filter C. Boost pressure too low D. Refer to “Engine Smoking (Black, Blue and/or White)” in previous troubleshooting chart
2. Loss of power	2. A. Not enough air getting to engine air intake B. Clogged air cleaner C. Boost pressure too low D. Poor lubrication of turbocharger E. Low oil pressure at turbocharger F. Rubbing of compressor or turbine impellers against housing G. Defective engine gaskets allowing air or fuel escape into exhaust or intake system
3. Unusual noises and vibrations at turbocharger	3. A. Poor lubrication of turbocharger B. Low oil pressure at turbocharger C. Rubbing of compressor or turbine impellers against housing D. Defective engine gaskets allowing air or fuel escape into exhaust or intake system
4. Rubbing of compressor or turbine impellers against housing	4. A. Poor lubrication of turbocharger B. Low oil pressure at turbocharger C. Defective bearings in turbocharger
5. Oil leakage from compressor side	5. A. Clogged air cleaner B. Boost pressure too low

Engine Noise

Important Information

No definite rule or test will positively determine source of engine noise; therefore, use the following information only as a general guide to engine noise diagnosis.

1. Noises timed with engine speed are related to crankshaft, rods, pistons, piston pins, and flywheel. Noises timed to one-half engine speed are valve train related.
2. The use of a stethoscope can aid in locating a noise source; however, because noise will travel to other metal parts not involved in the problem, caution must be exercised.
3. Try to isolate the noise to location in engine: front to back, top to bottom. This can help determine which components are at fault.
4. Sometimes noises can be caused by moving parts coming in contact with other components. Examples are: flywheel or coupler; exhaust flappers rattling against exhaust pipe; crankshaft striking (pan, pan baffle, or dipstick tube); rocker arm striking valve cover; and loose flywheel cover. In many cases if this is found to be the problem, a complete engine teardown is not necessary.
5. When noise is isolated to a certain area and component, removal and inspection will be required. Refer to proper sections of service manual for information required for service.
6. If noise cannot be distinguished between engine and drive unit, remove drive from boat. Run a water supply directly to engine. Run engine without the drive to determine if noise is still there.

Valve Cover Area

Location	Possible Cause
1. Valve cover area, timed to one-half engine speed, noise could be confined to one cylinder or may be found in any multitude of cylinders	1. A. Rocker arm striking valve cover B. Worn rocker arm C. Bent push rod D. Worn camshaft E. Sticking valve

Cylinder Area

Location	Possible Causes
1. Cylinder area, may be confined to one cylinder or found in more than one cylinder, timed to engine speed	1. A. Sticking valve B. Carbon build-up C. Connecting rod installed wrong D. Bent connecting rod E. Piston F. Piston rings G. Piston pin H. Cylinder worn

Cylinder Area (continued)

Location	Possible Causes
2. Engine knocking	1. A. Faulty injector (white smoke) B. Wrong injection timing C. Incorrect valve clearance D. Tight piston pin

Camshaft Area

Location	Possible Causes
1. Camshaft area, front of engine, timed to engine speed	1. A. Camshaft timing gear B. Fuel pump C. Valve lifter - camshaft wear D. Cam bearings
2. Camshaft area, center of engine, timed to engine speed	2. A. Fuel pump B. Valve lifter - camshaft wear C. Cam bearings
3. Camshaft area, rear of engine, timed to engine speed	3. A. Valve lifter - camshaft wear B. Cam bearings
4. Camshaft area, throughout engine, timed to engine speed	4. A. Loss of oil pressure B. Valve lifter - camshaft wear C. Cam bearings

Crankshaft Area

Location	Possible Causes
1. Crankshaft area, front of engine, timed to engine speed	1. A. Crankshaft timing gear B. Engine Oil Pump C. Rod bearing D. Main bearing
2. Crankshaft area, center of engine, timed to engine speed	2. A. Crankshaft striking pan or pan baffle B. Rod bearing C. Main bearing
3. Crankshaft area, rear of engine, timed to engine speed	3. A. Loose flywheel cover B. Loose coupler or drive plate C. Loose flywheel D. Rod bearing E. Main bearing
4. Crankshaft area, throughout engine, timed to engine speed	4. A. Loss of oil pressure B. Rod bearings C. Main bearings

Miscellaneous

Cause	Special Information
1. Hissing	1. A. Leaking exhaust (manifolds or pipes) B. Loose cylinder heads C. Blown head gasket
2. Whistle	2. A. Boost air leak B. Dry or tight bearing in an accessory
3. Squeaks or squeals	3. A. Drive belt slipping B. Dry or tight bearing in an accessory C. Parts rubbing together

Oil Pressure

Cause	Special Information
1. Measuring oil pressure	1. Use a good automotive oil pressure test gauge. Do not rely on the oil pressure gauge in the boat.
2. Check engine oil level with boat at rest in the water	2. Oil level should be between the ADD and FULL marks
3. Oil level in crankcase above FULL mark	3. May cause loss of engine RPM, oil pressure gauge fluctuation, drop in oil pressure, and hydraulic valve lifter noise at high RPM
4. Oil level in crankcase below ADD mark	4. Low oil pressure; oil pressure gauge fluctuation; internal engine noise and/or damage
5. Change in oil pressure	5. This may be a normal condition. Oil pressure may read high in the cooler times of the day, and when engine is not up to operating temperature. As the air temperature warms up and engine is running at normal opening temperature, it is nor mal for oil pressure to drop.
6. Low engine oil pressure at idle	6. With modern engines and engine oils, low oil pressure readings at idle do not necessarily mean there is a problem. If valve lifters do not “clatter” (at idle), there is a sufficient volume of oil to lubricate all internal moving parts properly. The reason for the drop in oil pressure is that engine heat causes an expansion of the internal tolerances in the engine and, also, the oil will thin out somewhat from heat.
7. Low engine oil pressure at idle after running at a high RPM	7. Refer to No. 5 and 6, preceding
8. Boats with dual engines	8. It is not uncommon to see different oil pressure readings between the two engines, as long as both engines fall within specifications. Differences in oil pressure can be attributed to differences in engine tolerances, gauges, wiring, senders, etc.
9. Boats with dual stations	9. Refer to No. 8. preceding

Low Oil Pressure

Cause	Special Information
1. Low oil level in crankcase	
2. Defective oil pressure gauge and/or sender	2. Verify with an automotive test gauge.
3. Thin or diluted oil	3. Oil broken down; contains water or fuel; wrong viscosity; engine running too hot or too cold; excessive idling in cold water (condensation)
4. Oil pump	4. Relief valve stuck open; pickup tube restricted; worn parts in oil pump; air leak on suction side of oil pump or pickup oil tube
5. Oil leak can be internal or external	5. Oil passage plugs leaking, cracked or porous cylinder block
6. Excessive bearing clearance	6. Cam bearings, main bearings, rod bearings

High Oil Pressure

IMPORTANT: Oil pressure slightly higher than normal does not always indicate a problem. Oil viscosity, and weather conditions could cause high oil pressure.

Cause	Special Information
1. Oil too thick	1. Wrong viscosity, oil full of sludge or tar
2. Defective oil pressure gauge and/or sender	2. Verify with an automotive test gauge
3. Clogged or restricted oil passage	
4. Oil pump relief valve stuck closed	

Excessive Oil Consumption

Cause	Special Information
1. Normal consumption	1. One quart of oil consumed in 5-15 hours of operation at wide-open-throttle (especially in a new or rebuilt engine) is normal
2. Oil leaks	2. Clean bilge, run engine with clean white paper on bilge floor, locate oil leak(s)
3. Oil too thin	3. Oil diluted or wrong viscosity
4. Oil level too high	
5. Drain holes in cylinder head plugged	5. Oil will flood valve guides
6. Defective valve stem seals (if so equipped)	
7. Intake manifold gasket leaking	
8. Worn valve stems or valve guides	
9. Defective oil cooler (if so equipped)	9. Crack in cooler tubes
10. Defective piston rings	10. Glazed, scuffed, worn, stuck, improperly installed; ring grooves worn; improper break-in; wrong end gap
11. Defective cylinders	11. Out of round, scored, tapered, glazed; excessive piston to cylinder clearance; cracked piston
12. Excessive bearing clearance	

Water in Engine

Important Information

IMPORTANT: First determine location of water in engine. This information can be of great help when trying to determine where the water came from and how it got into the engine. The three most common problems are “water on top of pistons, water in crankcase oil, water in crankcase oil and on top of pistons”.

The first step, after locating water, is to remove all the glow plugs and pumping cylinders out by cranking engine over. Next change oil and filter. Now, start engine and see if problem can be duplicated. If problem can be duplicated, there more than likely is a mechanical problem. If the problem cannot be duplicated, the problem is either an operator error or a problem that exists only under certain environmental conditions.

If water is contained to cylinder(s) only, it is usually entering through the intake system, exhaust system, or head gasket.

If the water is contained to crankcase only, it is usually caused by a cracked or porous block, a flooded bilge, or condensation.

If the water is located in both the cylinder(s) and the crankcase, it is usually caused by water in the cylinders getting past the rings and valves, or complete submersion.

Water In Crankcase Oil

Cause	Special Information
1. Water in boat bilge	1. Boat has been submerged or bilge water was high enough to run in through dipstick tube
2. Water seeping past piston rings or valves	2. Refer to “Water in Engine” (“Water On Top of Pistons”)
3. Engine running cold	3. Defective thermostat, missing thermostat; prolonged idling in cold water
4. Intake aftercooler leaking into manifold.	
5. Cracked or porous casting	5. Check cylinder head, cylinder block, and aftercooler.

Water On Top Pistons

Cause	Special Information
1. Rain water running onto air cleaner	1. Hatch cover
2. Backwash through the exhaust system	
3. Improper engine or exhaust hose installation	3. Refer to exhaust specifications
4. Cracked exhaust manifold	
5. Improper manifold to elbow gasket installation	
6. Loose cylinder head bolts	
7. Blown cylinder head gasket	7. Check for warped cylinder head or cylinder block
8. Porous or cracked casting	8. Check cylinder heads, cylinder block, and aftercooler.
9. Injector cups in cylinder head	

Engine Overheats (Cooling System)

Cause	Special Information
IMPORTANT: The first step is to verify if the engine is actually overheating or the temperature gauge or sender is faulty	
1. Seacock (seawater shutoff valve) partially or fully closed (if so equipped)	
2. Low coolant level	
3. Antifreeze not mixed properly	
4. Loose or broken drive belt	
5. Clogged sea strainer	
6. Improperly installed sea strainer	6. Mounted below level of seawater pump.

Engine Overheats (Cooling System) (continued)

Cause	Special Information
7. Loose hose connections between seawater pickup and seawater pump inlet (models with belt driven seawater pump only)	7. Pump will suck air. Pump may fail to prime or will force air bubbles into cooling system.
8. Seawater inlet hose kinked or collapsed	8. Inlet hose must be wire reinforced to prevent collapsing, and positioned to prevent kinks or restrictions.
9. Seawater pickup clogged	
10. Obstruction on boat bottom causing water turbulence	10. Obstruction will be in front of seawater pickup, causing air bubbles to be forced into cooling system.
11. Defective thermostat	
12. Exhaust elbow water outlet holes plugged	
13. Insufficient seawater pump operation	13. Worn pump impeller
14. Obstruction in cooling system such as casting flash, sand, rust, salt, etc.	14. Refer to water flow diagram for engine type being serviced
15. Engine circulating pump defective	
16. Heat exchanger cores plugged	
17. Also refer to “Engine Overheats (Mechanical)”	

Engine Overheats (Mechanical)

Cause	Special Information
1. Engine RPM below specifications at wide-open-throttle (engine laboring)	1. Damaged or wrong propeller; growth on boat bottom; false bottom full of water
2. Seawater pump impeller slipping	
3. Exhaust restriction	
4. Valve timing off	4. Gears improperly installed
5. Defective (blown) head gasket(s)	5. A defective (blown) head gasket(s) normally cannot be detected by a compression check. Normally the engine will run at normal temperature at low RPM, but will overheat at speeds above 3000 RPM.

Power Steering

Poor, Erratic, or No Assist

Cause	Special Information
1. Drive belt	1. Worn, broken or out of adjustment
2. Low fluid level	
3. Air in system	3. Air leak in lines, pump, or air from installation. Refer to Section 9A for bleeding procedure.
4. Leaking hoses	4. Refer to Section 9A for bleeding procedure.
5. Steering cables and/or steering helm	5. Cable or helm partially frozen from corrosion or rust; cable over-lubricated; improper cable installation
6. Binding in stern drive unit	6. Refer to appropriate Stern Drive Service Manual
7. Restriction in hydraulic hoses	7. Causes a loss of pressure
8. Control valve not positioned properly, not balanced properly, or the mounting nut is loose	
9. Mounting bracket adjusting screw loose or mounting tube is loose	
10. Faulty pump	10. Flow control valve may be sticking
11. Worn piston ring or scored housing bore in cylinder	11. Causes loss of pressure
12. Leaking valve body or loose fitting spool	

Noisy Pump

Cause	Special Information
1 Drive belt	1. Check belt tension
2. Low fluid level	
3. Air in fluid	3. Air leak in lines, pump, or air form installation
4. Faulty Pump	4. Use stethoscope to listen for noise in pump
5. Restricted fluid passages	5. Kinks or debris in hoses or debris in passages
6. Stop nut adjusted improperly	6. Refer to appropriate Stern Drive Service Manual
7. Steering cables installed that do not meet BIA standards	7. Refer to appropriate Stern Drive Service Manual

Fluid Leaks

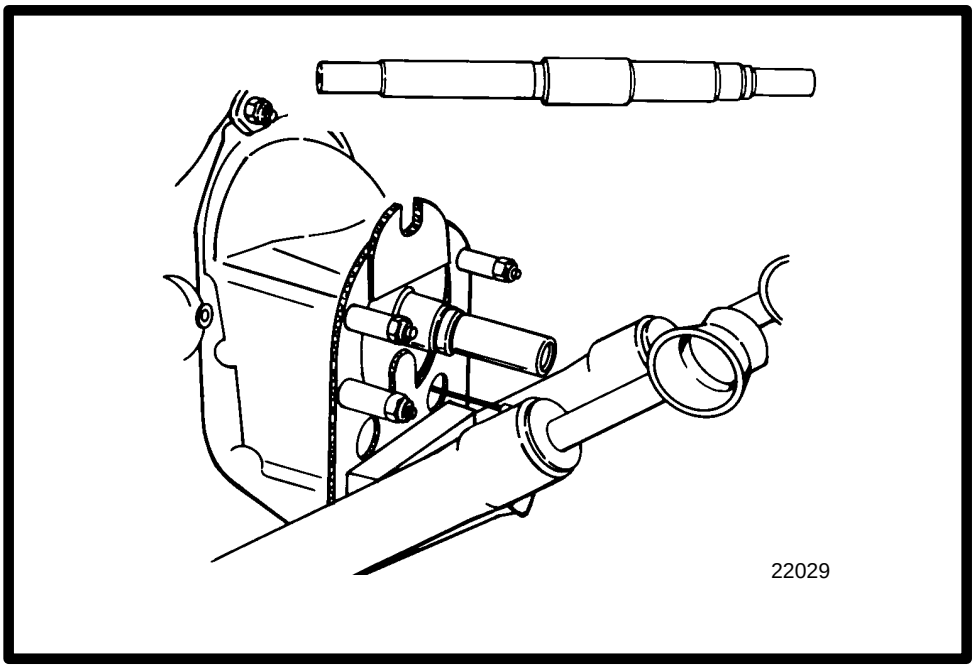
Cause	Special Information
1. Loose hose connections	1. Refer to Section 8A for bleeding instructions
2. Damaged hose	
3. Oil leaking from top of pump	3. System overfilled; fluid contains water; fluid contains air
4. Cylinder piston rod seal	
5. Faulty seals in valve	
6 Faulty seals in o-rings in pump	
7. Cracked or porous metal parts	

Insufficient Water Flow From Belt Driven Seawater Pump

Cause	Special Information
1. Drive belt	1. Loose, worn or broken
2. Seawater shutoff valve partially or fully closed	
3. Clogged sea strainer	
4. Improperly installed sea strainer	4. Sea strainer mounted below level of seawater pump.
5. Loose hose connections between seawater pick up and seawater pump inlet	5. Pump will suck air, pump may fail to prime or will force air bubbles into cooling system
6. Seawater inlet hose kinked or plugged	
7. Seawater pickup plugged	
8. Obstruction on boat bottom causing water turbulence	8. Obstruction will be in front of seawater pickup, causing air bubbles to be forced into cooling system
9. Faulty seawater pump	

REMOVAL AND INSTALLATION

2
A



MCM (STERNDRIVE) MODEL

Index

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Torque Specifications

IMPORTANT: Listed below are the torque specifications for those fasteners which have a specific torque value. Tighten all other fasteners (not listed) securely.

Fastener Location		Lb. Ft. (N·m)	Lb. In. (N·m)
Drive Unit Shift Cable or Power Shift Output Cable End Guide Attaching Nut		Tighten Nut Until It Bottoms Out Against Flat Washer; then, Back Nut Off 1 Turn	
Remote Control Throttle Cable End Guide Attaching Nut		Tighten Nut Until It Bottoms Out Against Flat Washer; then, Back Nut Off 1 Turn	
Remote Control Throttle and Shift Cable Barrel Attaching Nut		Securely	
Rear Engine Mounts		35-40 (47-54)	
Power Steering Fluid Hose Fittings (at Control Valve)		20-25 (27-34)	
Sterndrive Unit Fasteners		50 (68)	
Transom Assembly Fasteners		20-25 (27-34)	
Seawater Pickup Block-Off Plate (on gimbal housing)			45 (5)
Drive Unit Gear Lube Monitor - 90 Degree Barb Fitting			70-90 (8-10)
Steering Cable Pivot Bolts		25 (34)	
Steering Cable Coupler Nut		35 (47)	
Bravo Three Propeller Nuts	Front	100 (136) MINIMUM	
	Rear	60 (81) MINIMUM	

Tools/Lubricants/Adhesives

Part Number	Description
92-825407A2	Quicksilver 2-4-C Marine Lubricant
92-13872A1	Quicksilver Special Lubricant 101
92-25711-2	Quicksilver Liquid Neoprene
92-34227-1	Quicksilver Perfect Seal
91-805475A1	Quicksilver Engine Alignment Tool [or old tool (91-57797A3) which has been modified per OEM Service Bulletin 92-4]
91-816391A4	Quicksilver Engine Coupler Spline Grease
91-806205A1	Engine Mount Installation Tool
Obtain Locally	# 592 - Loctite Pipe Sealant with Teflon

Engine Removal

IMPORTANT: Sterndrive unit must be removed prior to engine removal. Refer to Sterndrive Service Manual.

1. Disconnect battery cables from battery.
2. Remove instrument harness connector plug from engine harness receptacle.

⚠ CAUTION

It is good practice to ventilate the engine compartment prior to servicing any engine components to remove any fuel vapors which may cause difficulty breathing or be an irritant.

⚠ WARNING

Be careful when changing fuel system components; diesel fuel is flammable. Be sure that the ignition key is OFF. DO NOT smoke or allow sources of open flame in the area while changing fuel system components. Wipe up any spilled fuel immediately. DO NOT allow fuel to come into contact with any hot surface which may cause it to ignite.

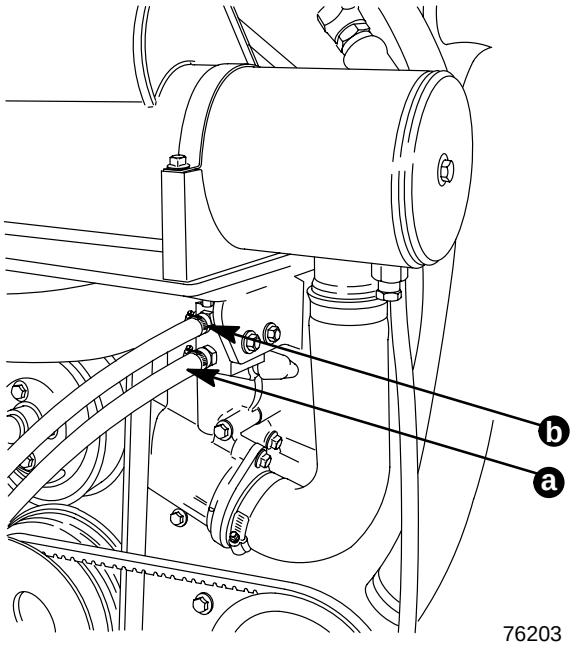
⚠ WARNING

Dispose of fuel-soaked rags, paper, etc., in an appropriate air tight, fire retardant container. Fuel-soaked items may spontaneously ignite and result in a fire hazard which could cause serious bodily injury or death.

⚠ WARNING

FIRE HAZARD: Fuel leakage from any part of the fuel system can be a fire hazard which can cause serious bodily injury or death.

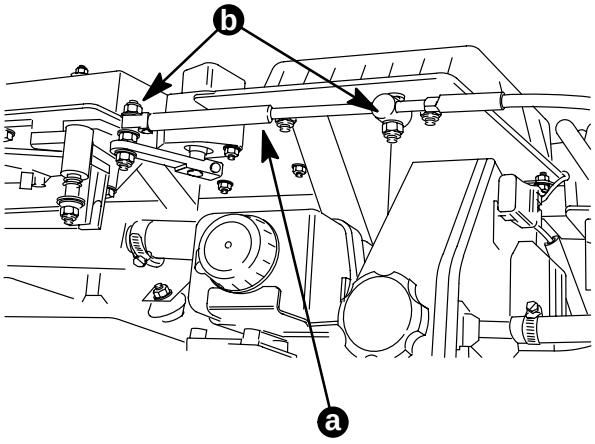
3. Loosen hose clamp, then disconnect and suitably plug fuel lines to prevent fuel in tank from leaking into bilge.



76203

a - Fuel Supply Line
b - Fuel Return Line

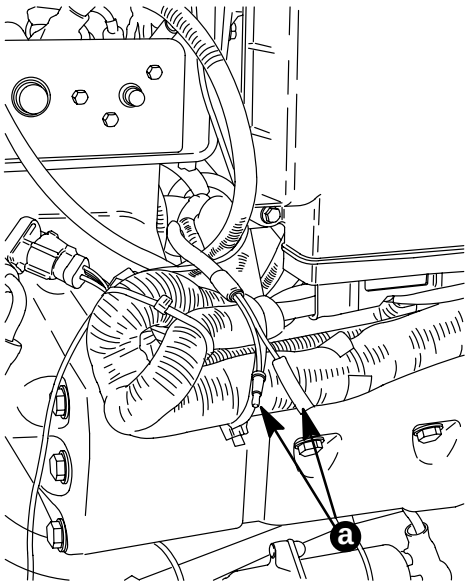
4. Disconnect throttle cable from linkage on engine and retain locknuts and hardware.



76207

a - Throttle Cable
b - Locknuts and Washers

5. Disconnect bullet connectors of trim sender wires (coming from transom assembly) from engine harness.

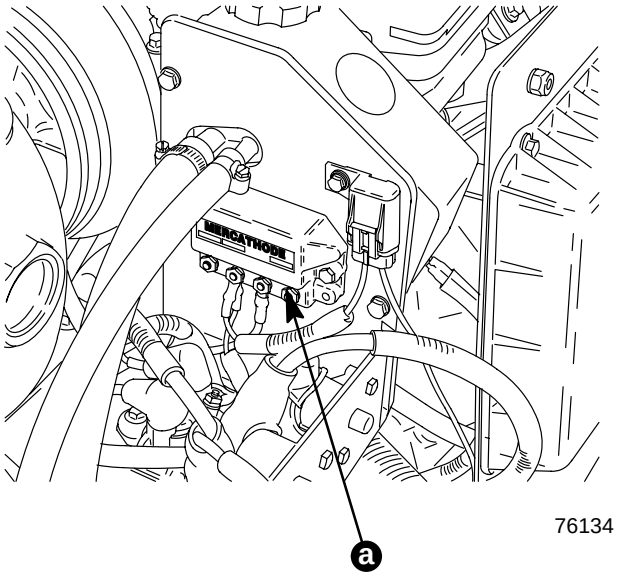


76135

a - Trim Sender Connectors

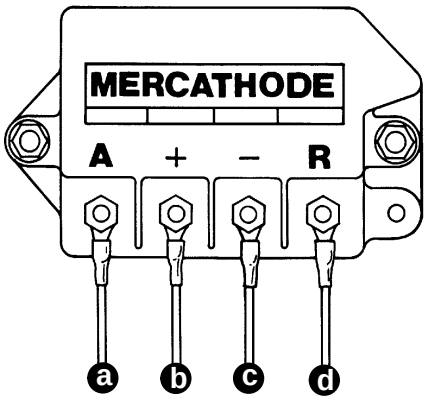
NOTE: *After wires are disconnected be sure to loosen them from clamps or sta-straps retaining them to engine or hoses.*

6. Disconnect MerCathode wires from MerCathode controller mounted on engine.



76134

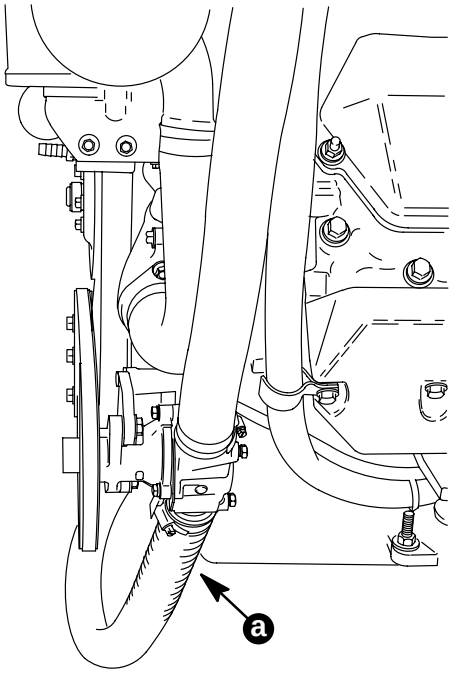
a - MerCathode Controller



22232

a - Orange Wire - From Electrode on Transom Assembly
b - Red/Purple Wire - Connect (Other End) to Positive (+) Battery Terminal
c - Black Wire - From Engine Harness
d - Brown Wire - From Electrode on Transom Assembly

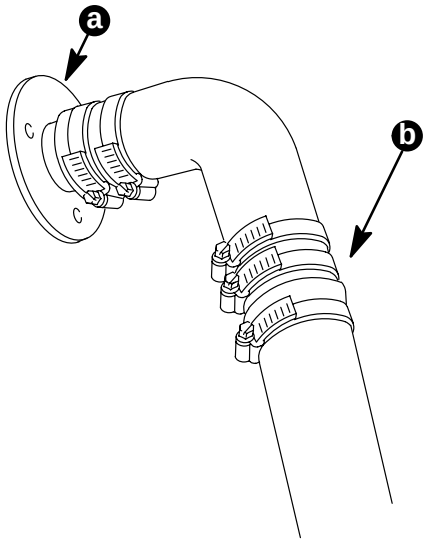
7. Disconnect seawater inlet hose from seawater pump.



76107

a - Seawater Inlet Hose

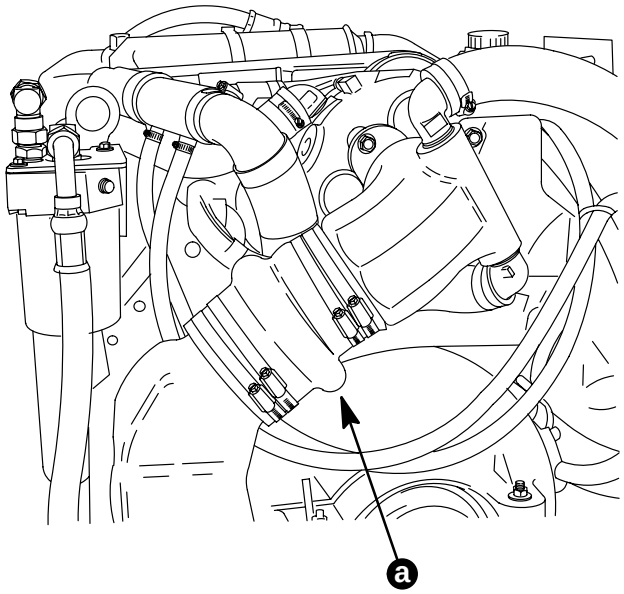
8. Disconnect water bypass hose from overboard discharge fitting.



76139

a - Seawater Overboard Discharge Fitting
b - Seawater Hose

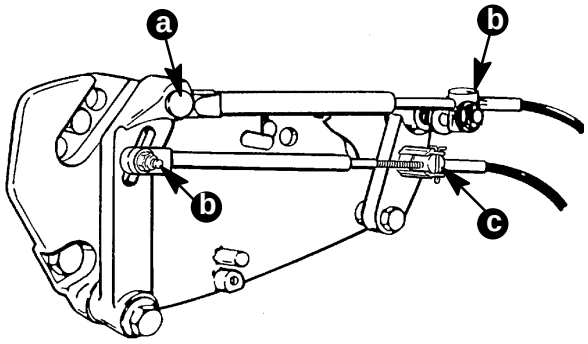
9. Disconnect exhaust elbow hose from exhaust pipe.



76106

a - Exhaust Pipe Hose

10. Remove both shift cables from shift plate. Retain locknuts and hardware.

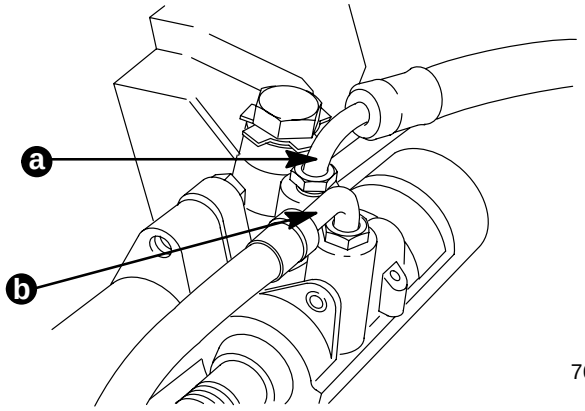


72016

a - Pin And Cotter Pin
b - Locknut And Washers
c - Cotter Pin

11. Disconnect any grounding wires and accessories that are connected to engine.

12. Disconnect (and suitably plug) fluid hoses from power steering control valve on transom.



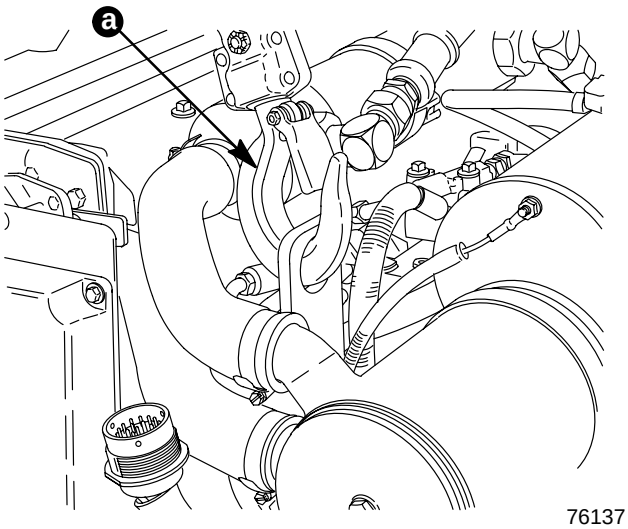
76211

a - Rear Fitting (Pressure Hose)
b - Front Fitting (Return Hose)

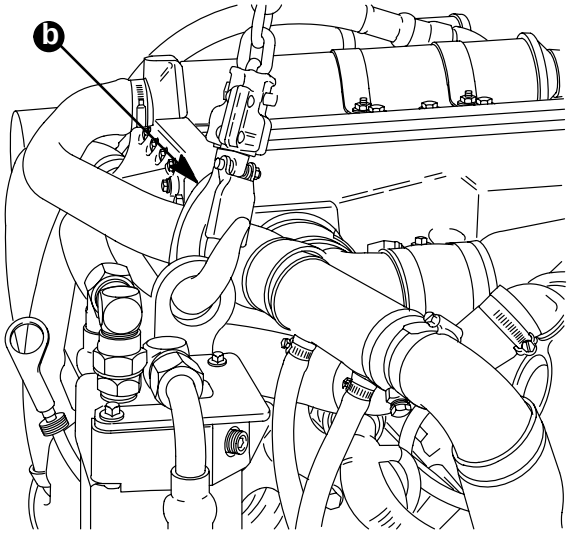
⚠CAUTION

DO NOT allow lifting sling to hook or compress engine components or damage will occur.

13. Support engine with suitable sling, through lifting eyes on engine and remove front and rear engine mounting bolts. Retain hardware.



76137



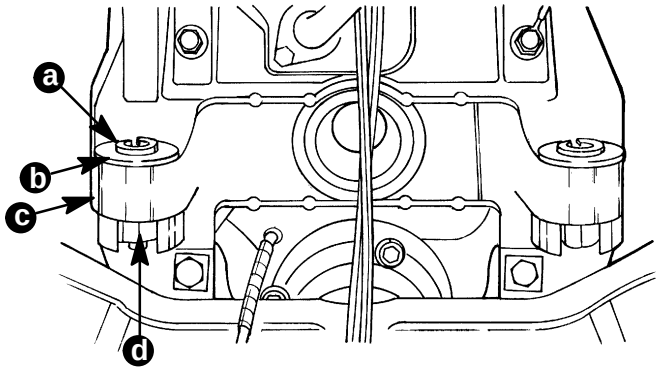
76138

a - Front Lifting Eye
b - Rear Lifting Eye

14. Carefully remove engine. DO NOT hit power steering control valve.

Engine Installation/Alignment

1. Follow instructions “a” - “e”:
   a. Be certain fiber washers (cemented in place) on inner transom plate are present. Inspect fiber washers. Replace if worn or damaged.
   b. Install double wound lockwashers onto inner transom plate inside fiber washer.
   c. Be certain rear engine mount locknuts are in position as shown.
   d. Lubricate exhaust hose with soap and water to ease installation.
   e. Lubricate engine coupler splines with Quicksilver Engine Coupler Spline Grease.



72023

a - Double Wound Lockwasher
b - Fiber Washer (Cemented in Place)
c - Inner Transom Plate Mount (Engine Support)
d - Locknuts (Engine Mounting Bolts)

⚠ CAUTION

DO NOT allow lifting sling to hook or compress engine components or damage will occur.

2. Attach a suitable sling to lifting eyes on engine and adjust so that engine is level when suspended. **(Refer to "Removal" section as previously outlined for location of lifting eyes.)**
3. Lift engine into position (in boat), using an overhead hoist.

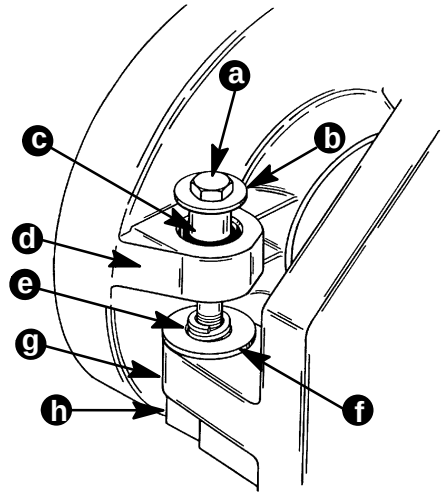
⚠ CAUTION

When lowering engine into position DO NOT set engine on shift cable. Shift cable outer casing can be crushed causing difficult or improper shifting.

4. Align rear engine mounts with inner transom plate mounts and set onto front engine mounts and inner transom plate mounts, while simultaneously aligning exhaust elbow with exhaust tube as shown. (Do not relieve hoist tension.)

IMPORTANT: Engine attaching hardware must be installed in sequence shown.

5. Install both rear engine mounting bolts and hardware as shown. Torque to 35-40 lb. ft. (47-54 N·m).



72535

a - Bolt, Rear Engine Mounting
b - Washer, Large Steel
c - Spacer, Metal
d - Rear Engine Mount
e - Double Wound Lockwasher
f - Fiber Washer
g - Inner Transom Plate Mounts
h - Locknut (Hidden in This View)

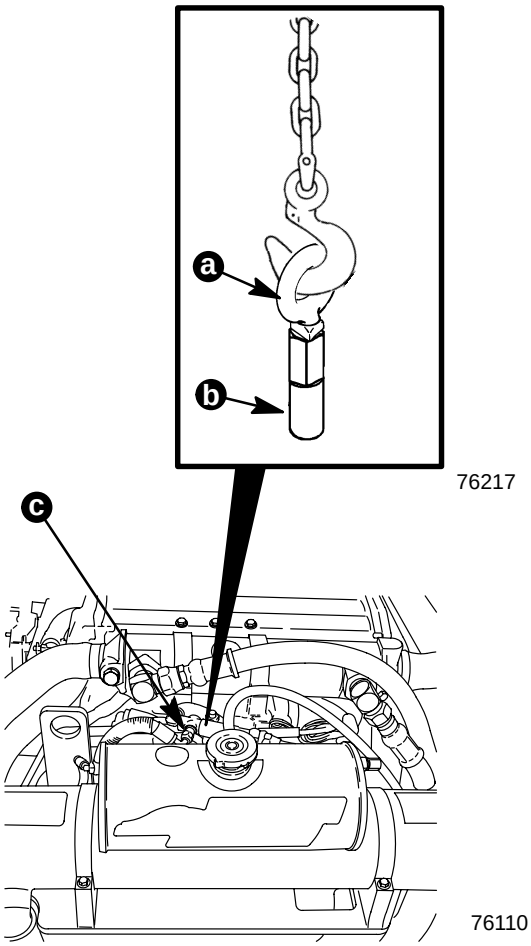
6. Relieve hoist tension and disconnect sling from engine lifting eyes.

NOTE: *Install Engine Lifting Eye Tool shown in following steps to help equalize load on hoist during alignment procedure.*

⚠ CAUTION

Avoid injury or damage to product. Engine Lifting Eye Tool must be used for alignment procedures only and is NOT to be used for *installing* the engine in the boat.

7. Install Engine Lifting Eye Tool 91-806451 into Lifting Eye Extension Tool 91-806442. Tighten securely. Install Extension Tool with Lifting Eye into threaded hole in engine lifting bar as shown. Tighten securely, but do not overtighten. Attach chain and hook from suitable hoist. Position hoist so as to lift the engine vertically when raised.

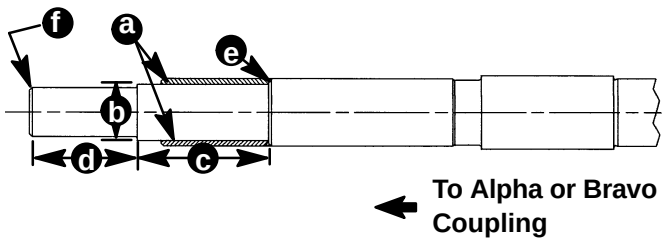


76217

76110

a - Engine Lifting Eye Tool
b - Lifting Eye Extension Tool
c - Engine Lifting Bar

Quicksilver Engine Alignment Tool (91-57797A3) Modification:



a - Material To Be Removed (Shaded Area)
b - Measurement - 1.150 in. (29.21 mm)
c - Measurement - 2.750 in. (69.85 mm)
d - Measurement - 2.200 in. (55.88 mm)
e - Radius - .060 (1.5 mm)
f - Chamfer - .060 in. (1.5 mm) x 45 degree

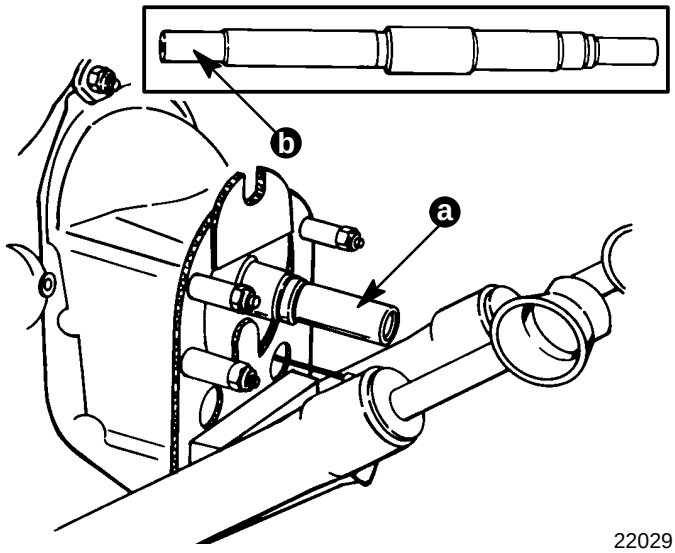
IMPORTANT: The modified 91-57797A3 tool or the new tool 91-805475A1 will align all current Alpha One or Bravo models as well as all older engines that used the older 91-57797A3.

⚠CAUTION

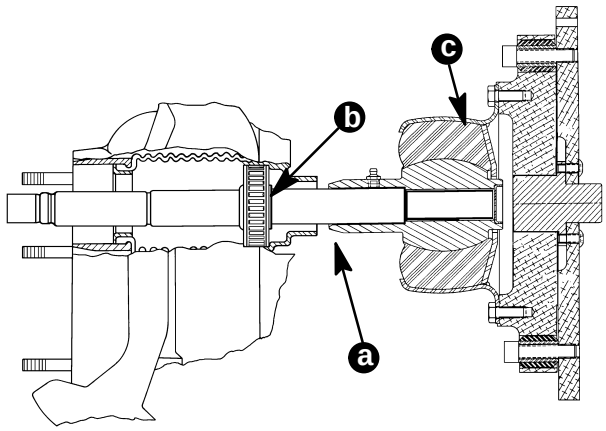
To avoid damage to gimbal bearing, engine coupler, or alignment tool:

- **DO NOT attempt to force alignment tool!**
- **DO NOT raise or lower engine with alignment tool inserted (or partially inserted) in gimbal bearing or engine coupler.**

8. Align engine as follows:
   a. Attempt to insert solid end of Quicksilver Alignment Tool through gimbal bearing and into engine coupler splines.
   b. If the tool does not fit, remove it and carefully raise or loser the front end of the engine, as necessary, and attempt to insert the alignment tool.
   c. Repeat step “c” until the alignment tool installs easily **(SLIDES FREELY WITH TWO FINGERS)** all the way into and out of engine coupler splines. Do not check by turning.



22029



76218

a - Alignment Tool
b - Gimbal Bearing
c - Engine Coupler

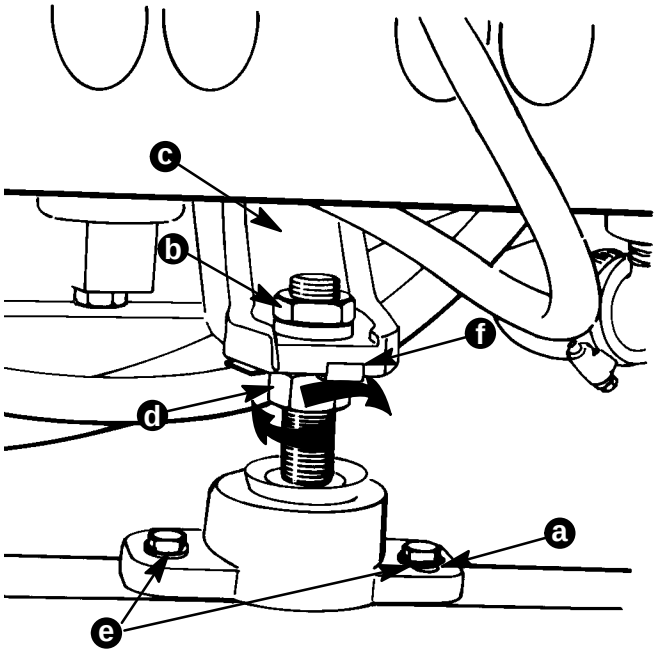
IMPORTANT: Turn both front engine mount adjustment nuts an equal amount in direction required to align engine.

   d. Adjust front engine mounts until they rest on boat stringers.
   e. Relieve hoist tension entirely and fasten both front mounts to boat stringer using appropriate hardware (lag bolts or thru-bolts, etc.).
   f. Recheck alignment with alignment tool. Tool must enter coupler splines freely. If not, readjust front mounts.

g. When alignment is correct, tighten locknut or nut with lockwasher on each mount securely.

h. Bend tab washer down against flat on adjusting nut.

i. Remove alignment tool if not already removed.



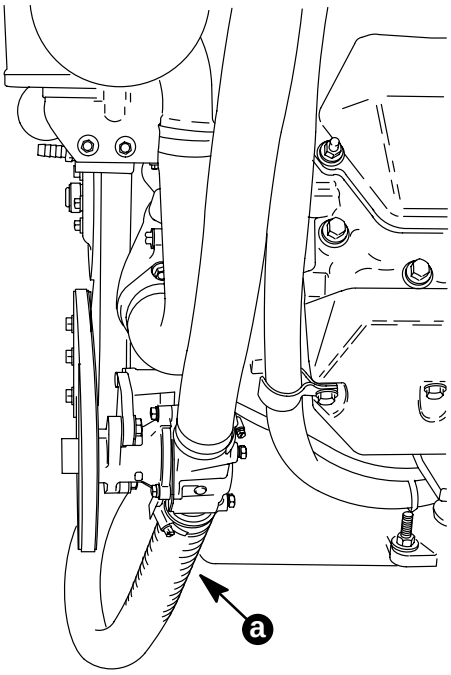
71969

a - Slotted Hole Toward Front of Engine
b - Lock Nut
c - Bracket
d - Mount Adjustment Nut - turn left to lower, right to raise
e - Lag Screws (or Bolts)
f - Tab Washer

Engine Connections

IMPORTANT: When routing all wire harnesses and hoses, be sure they are routed and secured to avoid coming in contact with hot spots on engine and avoid contact with moving parts.

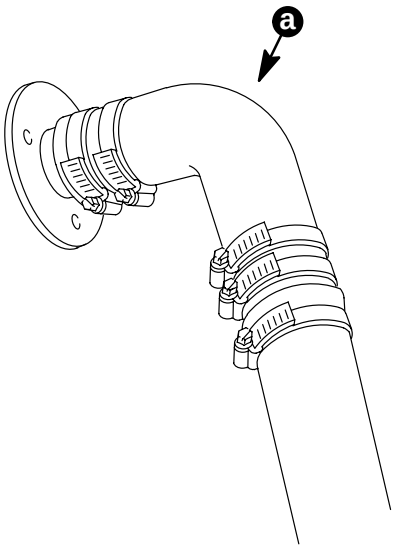
1. Connect seawater inlet hose to pump. Tighten hose clamp securely.



76107

a - Seawater Inlet Hose

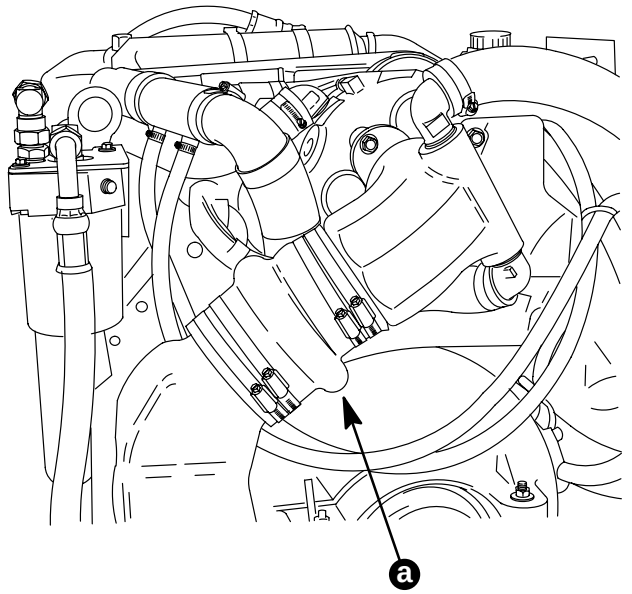
2. Connect seawater bypass hose from exhaust elbow to overboard discharge fitting. Tighten clamps securely.



76139

a - Seawater Inlet Hose To Overboard Discharge Fitting

3. Tighten exhaust system hose clamps securely. Use two hose clamps (each side) on exhaust hose connections.



a - Exhaust Hose

⚠ WARNING

Be careful when working on fuel system components; diesel fuel is flammable. Be sure that the ignition key is OFF. DO NOT smoke or allow sources of open flame in the area while changing fuel system components. Wipe up any spilled fuel immediately. DO NOT allow fuel to come into contact with any hot surface which may cause it to ignite.

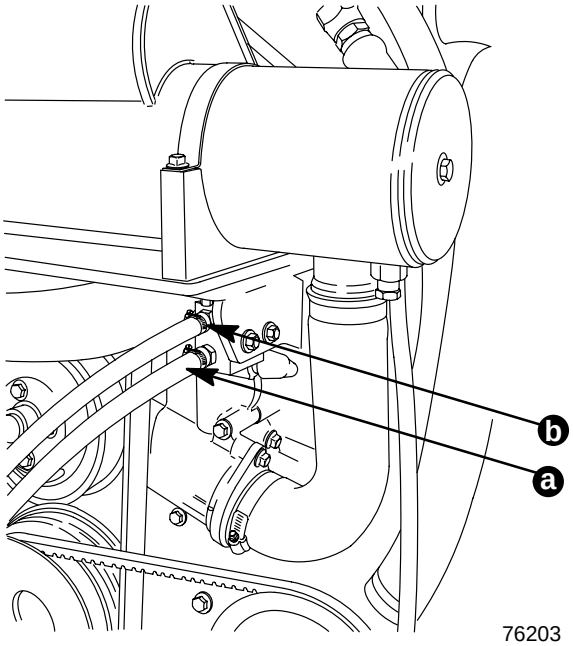
⚠ WARNING

FIRE HAZARD: Fuel leakage from any part of the fuel system can be a fire hazard which can cause serious bodily injury or death.

⚠ WARNING

Dispose of fuel-soaked rags, paper, etc., in an appropriate air tight, fire retardant container. Fuel-soaked items may spontaneously ignite and result in a fire hazard which could cause serious bodily injury or death.

4. Connect fuel lines from fuel tank(s) to engine following instructions “a” and “b”. Make certain connections are secure.
   a. Connect flexible fuel **inlet** line from fuel tank to ***lower*** fitting on fuel distribution block and secure as appropriate to boat connections.
   b. Connect flexible fuel **return** line to ***upper*** fitting on fuel distribution block and secure as appropriate to boat connections.



a - Inlet Fitting
b - Return Fitting

NOTE: *In the above drawing, fuel hoses would be connected to barb fittings and secured with hose clamps. Connect as appropriate to your boat manufacturer.*

5. Check for leaks.

IMPORTANT: After fluid hose installation in the following, bleed power steering system as outlined in appropriate Sterndrive Service Manual.

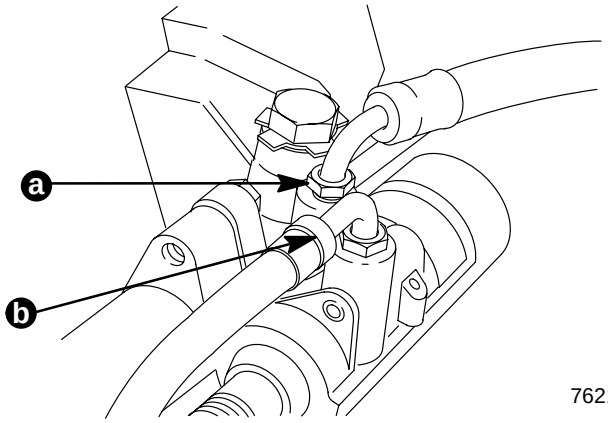
6. Connect power steering hoses to control valve. Torque fittings to 20-25 lb. ft. (27-34 N·m).

⚠ CAUTION

Route hoses exactly as shown below. This will help avoid stress on the hose fittings and will help avoid kinks in the hose.

IMPORTANT: Make hydraulic connections as quickly as possible to prevent oil leakage.

IMPORTANT: Be careful not cross-thread or overtighten hose fittings.

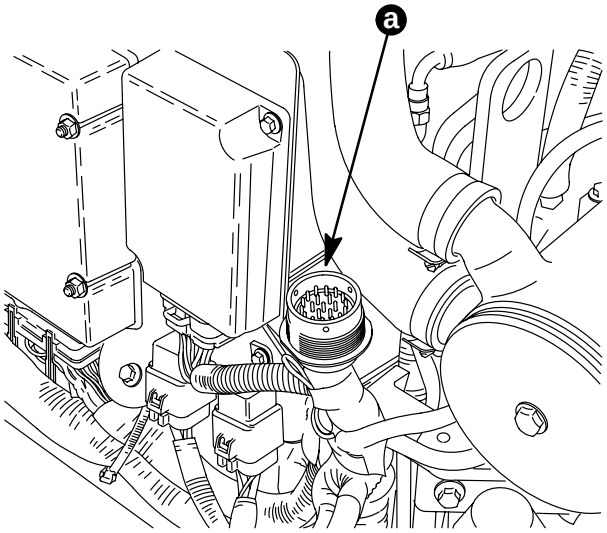


76211

a - Rear Fitting (Pressure Hose)
b - Front Fitting (Return Hose)

IMPORTANT: When routing all wire harnesses and hoses, be sure they are routed and secured to avoid coming in contact with hot spots on engine and avoid contact with moving parts.

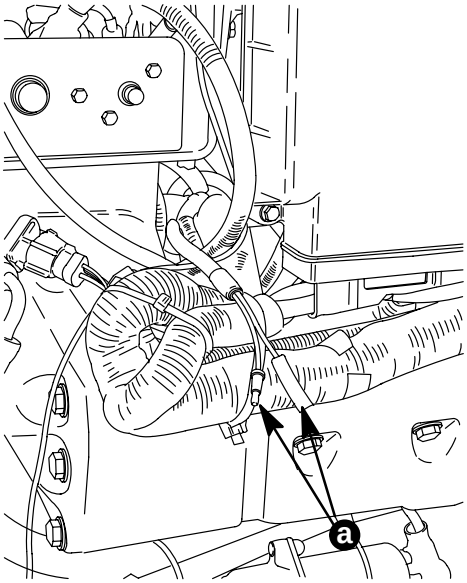
7. Connect instrument extension harness to engine harness - connector collars must be fully engaged and secure.



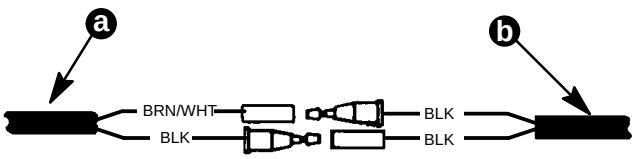
76103

a - Engine Harness Connector

8. Connect trim position sender leads from gimbal housing to leads from engine harness.



76135



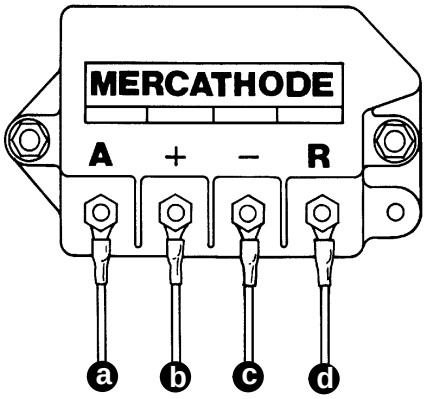
24841

a - Trim Sender Wires From Engine Harness
b - Trim Sender Wires From Gimbal Housing

9. Connect any grounding wires or accessories that may have been disconnected.

IMPORTANT: Do not attach any accessory ground (–) wires to transom plate ground point. Accessory ground wires should only be attached to ground stud on engine.

10. Connect wires to MerCathode controller assembly as shown. Apply a thin coat of Quicksilver Liquid Neoprene to all connections.



22232

a - Orange Wire - From Electrode on Transom Assembly
b - Red/Purple Wire - Connect (Other End) to Positive (+) Battery Terminal
c - Black Wire - From Engine Harness
d - Brown Wire - From Electrode on Transom Assembly

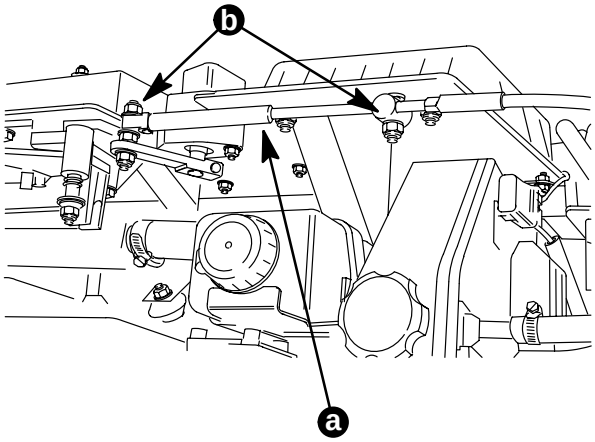
11. Connect throttle cable using hardware retained and adjust as follows:

    a. Place remote control handle(s) in neutral, idle position.

IMPORTANT: Be sure that cable is routed in such a way as to avoid sharp bends and/or contact with moving parts. DO NOT fasten any items to throttle cable. Outer cable must be free to move when cable is actuated.

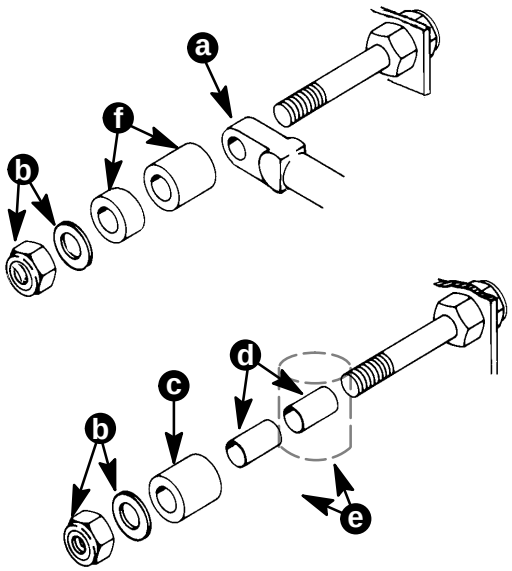
    b. Install cable end guide on throttle lever, then push cable barrel lightly toward throttle lever end. (This will place a slight preload on cable to avoid slack in cable when moving remote control lever.) Adjust barrel on throttle cable to align with anchor stud.

    c. Secure throttle cable with hardware (retained) as shown. Tighten cable end guide nut until it bottoms out and then back off one full turn. Tighten cable barrel securely. DO NOT OVER-TIGHTEN, as cable must pivot freely.

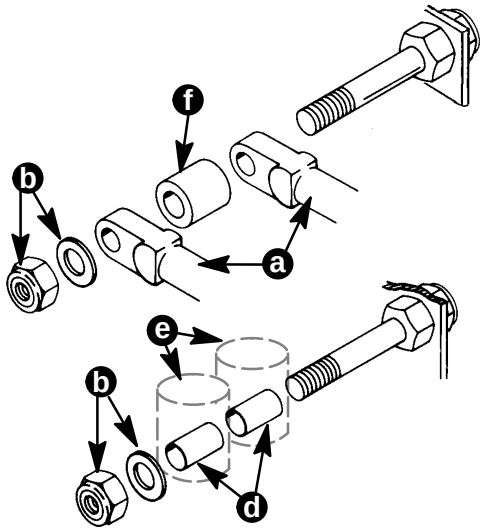


76207

a - Cable End Guide
b - Locknuts and Washers



Single Cable Installations



73348

Dual Cable Installations

a - Cable End Guide(s)
b - Locknuts and Washers
c - Spacer (Fits Over Bushings)
d - Bushings [Fit Inside Spacer or Cable Barrel(s)]
e - Cable Barrel(s) (Shown Dashed to Reveal Bushings)
f - Spacer (Fits Over Stud)

12. Check to ensure that remote control and cable are providing proper output.

13. Refer to appropriate Sterndrive Service Manual to install and adjust drive unit and remote control shift cables, using hardware retained.

IMPORTANT: Adjust shift cables as outlined in appropriate Sterndrive Service Manual.

14. Connect battery cables to battery by FIRST connecting positive (+) battery cable (usually red) to positive (+) battery terminal. Tighten clamp securely. Then, connect negative (–) battery cable (usually black) to negative (–) battery terminal. Tighten clamp securely.

NOTE: *Spray terminals with a battery connection sealant to help retard corrosion.*

Torque Specifications

IMPORTANT: Fasteners not listed should be tightened securely.

Item / Fastener Location	Lb. Ft	Lb. In.	N·m
Alternator Brace to Alternator		192	28
Alternator Brace to Bracket	30		41
Alternator to Mounting Bracket	35		48
Alternator Mounting Bracket	30		41
Camshaft Gear	15		20
Camshaft Thrust Flange Bolts	14		19
Connecting Rod Cap (Note 1)	51		69
Crankcase Front Cover	14		19
Crankshaft Pulley	35		48
Cylinder Head (Note 2)	100		135
Exhaust Manifold	35		48
Flywheel (Note 3)	47 + 45°		64 + 45°
Flywheel Coupler	35		48
Flywheel Housing to Block	60		80
Front Mount Bracket	30		41
Fuel Injection Nozzles	35		48
Fuel Pump	25		34
Glow Plugs		144	16
Intake Manifold	35		48
Main Bearing Cap (Note 4)	95 + 45°		129 + 45°
Oil Pan		168	19
Oil Pan Drain Plug	28		37
Oil Pickup Tube		168	19
Oil Pump		168	19
Rear Main Cover		168	19
Rear Mount (MCM)	40		54
Rocker Arm Bolts	20		27
Rocker Arm Cover		72	8
Roller Lifter Restrictor Retainer Plate		144	16
Seawater Pump Brace	30		41
Seawater Pump Bracket	30		41

Note 1: *Tighten both rod cap nuts to 38 lb. ft. (51 N·m) before final torque is applied.*
Note 2: *Refer to section for special torque steps and sequence before final torque is applied.*
Note 3: *Apply Quicksilver Perfect Seal to threads of all bolts prior to assembly. After final torque is applied, rotate fasteners through the specified torque angle.*
Note 4: *Tighten four main bearing cap bolts to 75 lb. ft. (102 N·m) before final torque is applied. Then, rotate fasteners through the specified torque angle.*

Torque Specifications (continued)

IMPORTANT: Fasteners not listed should be tightened securely.

Item / Fastener Location	Lb. Ft	Lb. In.	N·m
Starter Motor	50		68
Torsional Damper	90		122
Water Circulating Pump		168	19

Tools/Lubricants/Sealants

TOOLS/LUBRICANTS/SEALANTS	
Description	**Part Number**
Piston Ring Expander	91-24697
Quicksilver Loctite A	92-32609 1
Quicksilver Perfect Seal	92-34227
Quicksilver Needle Bearing Assembly Lubricant	92-42649A1
Quicksilver RTV Sealer	92-91601 1
Walker - T95® Sealant	92-808137
Cam and Lifter Prelube	Obtain Locally
Aviation Permatex #3	
Loctite Hydraulic Sealant	
AGS PE-12 Solvent and Penetrating Fluid	

Special Tools

SPECIAL TOOLS	
Description	**Part Number**
BRM Flex Hone® Can be ordered from: Brush Research Manufacturing Company, Inc. 4642 East Floral Drive Los Angeles, CA 90022 Phone: (213) 261-2193	GBD4-1/8

OTC SPECIAL TOOLS	
Can be ordered from:	OTC Division 655 Eisenhower Drive Owatonna, MN 55060 Phone: 1-800-533-5338 or 1-800-533-0492 Fax: 1-800-283-8665
Description	**Part Number**
Camshaft Bearing Remover/Installer	ZTSE-1897-0
Camshaft Gear Installer	ZTSE-1900-69
Camshaft Remover/Installer	ZTSE-1880-D
Connecting Rod Bearing Remover/Installer	ZTSE-4154
Connecting Rod Guide Protector Caps	ZTSE-4153
Front Oil Seal Installer	ZTSE-4130
Hydraulic Lifter Leakdown Tester	ZTSE-1893
Rear Oil Seal Installer	ZTSE-4131
Crankshaft and Camshaft Gear Remover	ZTSE-2295-69
Crankshaft and Camshaft Gear Installer	ZTSE-1900-69
Valve Spring Compressor	ZTSE-1846
Valve Spring Tester	ZTSE-2241
Expansion Plug Replacer	ZTSE-4155A
Fuel Pump Cam Remover/Installer	SE-4156
Valve Guide Bore Gauge	SE-2506
Main Bearing Remover/Installer	J-8080
Air Line Adaptor Tool	J-23590
Valve Spring Compressor	J-5892
Top Ring Groove Gauge Pins (.115 Inch)	ZTSE 3020-1
Intermediate Ring Groove Gauge Pins (.098 Inch)	ZTSE 3020-3
Orificed Restrictor Tool	SE-4146

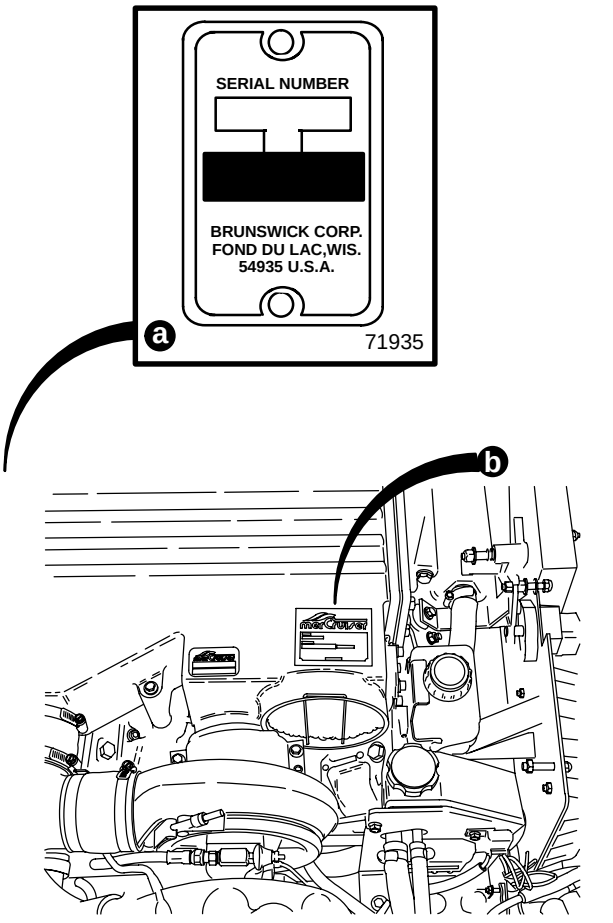
General

Some of the repairs in this section must be completed with engine removed from boat. Engine removal depends upon type of repair and boat design. Place engine on repair stand for major repairs.

Lubricate all moving parts (during reassembly) with engine oil. Apply Quicksilver Perfect Seal on threads of and under all cylinder block external bolts, screws and studs.

Engine Identification

The permanent engine serial number is stamped on the top left side of the engine block.



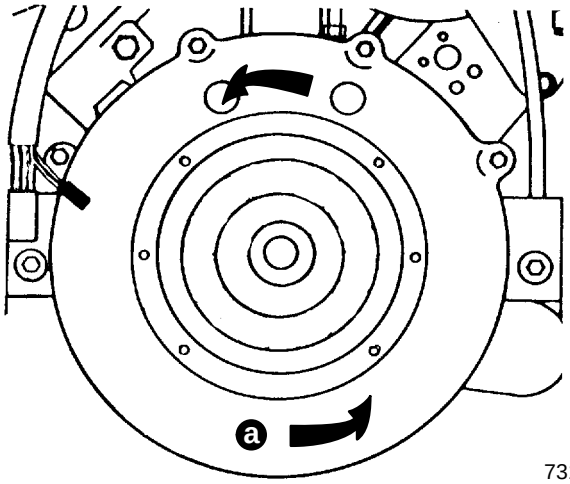
a - Riveted Serial Number Plate (Top, PortSide of Engine Block)
b - Self-Adhesive Serial Number Plate Applied to Top of Intercooler

Engine Rotation

Engine rotation terminology, at times, has caused confusion. To clarify, engine rotation is determined by observing flywheel rotation from the rear (transmission or stern drive end) of the engine looking forward (water pump end).

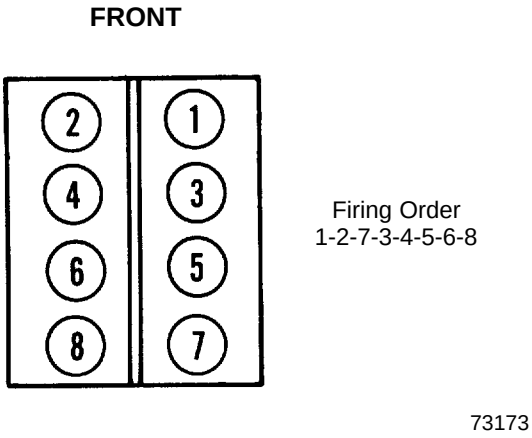
Propeller rotation is not necessarily the same as engine rotation.

The D7.3L/270 diesel engine covered in this manual has left-hand (CCW) rotation.



a - Left-Hand Rotation (CCW)

Engine Firing Order



Firing Order
1-2-7-3-4-5-6-8

Description

Crankshaft

The crankshaft is made of forged steel and supported in the block by five insert type bearings. Crankshaft end thrust is controlled by flanges on the No. 5 bearing. A torsional damper on the forward end of the crankshaft serves to dampen any engine torsional vibration.

A helical gear on the forward end of the crankshaft drives the camshaft.

Piston and Connecting Rods

Pistons are made of an aluminum alloy; connecting rods of forged steel.

Piston pins are of the free floating type permitting the pin to move or float freely in the piston and rod. The pin is held in place with retaining rings.

The D7.3L engine piston crown is anodized. This anodized surface is more resistant to cracks caused by the increased firing pressures and combustion temperatures associated with turbocharging.

The piston pin outer diameter has been increased verses the normally aspirated engine to assure reliability of the piston pin.

The top compression and intermediate ring on the D7.3L are a Keystone design (trapezoidal or tapered). The top ring is designed at a 15° angle, while the intermediate ring is at a 6° angle. These features improve ring life and decrease the potential for ring sticking. The oil control ring is a conventional rectangular design.

Because of the Keystone ring design, measurement of the ring groove *wear* must be accomplished in a special manner, as outlined later in this section.

Camshaft and Drive

Camshafts are made of steel. All camshafts are driven at one-half crankshaft speed by timing gears, and are supported by five main bearings, which are pressed into the block. The end thrust of the camshaft is controlled by a thrust flange located between the front camshaft journal and thrust flange spacer.

On engines with steel camshaft and roller lifters, eight lifter restrictors, held in place by a retaining plate, hold the hydraulic valve lifters from rotating.

Cylinder Head

The cylinder head assemblies are made of cast iron, which provide superior combustion characteristics. Graphite composition head gaskets are used to retard corrosion.

Valve Train

The valves and valve springs are of a heavy-duty design to withstand the high engine speeds encountered. Intake and exhaust valve rotators are used to help extend valve life.

Hydraulic valve roller lifters ride directly on the camshaft lobes and transmit the thrust of the lobes to the push rods which in turn actuate the valves through the rocker arm.

In addition to transmitting thrust of the cam lobes, the hydraulic roller lifters also serve to minimize engine noise and remove any clearance (lash) from the valve train thereby keeping all parts in constant contact.

The valve lifters also are used to lubricate the valve train bearing surfaces.

Lubrication System

The lubrication system is pressure regulated, cooled and full flow filtered. In addition to providing engine lubrication, pressurized lube oil is used to control fuel delivery in the hydraulically actuated electronically controlled unit injectors.

SUMP, PICK–UP TUBE, PUMP, OIL COOLER AND FILTER

Lube oil is drawn from the oil sump through the pick–up screen, and tube into the oil pump. The oil pump is of the Gerotor type with the rotor portion driven directly by flats on the nose of the crankshaft. The pump housing is bolted to the front cover. Pump inlet and outlet passages are through ports in the front cover. Lube oil enters the oil cooler header through a passage in the front cover. (At initial engine startup, a small portion of the oil is passed directly from the pump to the oil reservoir situated on the top of the front cover. This will be covered in more details later in this section). Oil flows from the oil cooler header around the oil cooler tubes to the oil filter assembly. Filtered oil then passes through the filter (from element outside to inside) to the main oil gallery in the crankcase. The oil pressure regulator controls lube oil pressure via a spring loaded plunger which relieves oil back to sump once operating pressure is reached. The filter housing also contains a by–pass valve allowing oil to pass directly to the main oil gallery should the filter become excessively restricted.

MAIN BEARINGS, ROD BEARINGS AND CAMSHAFT JOURNALS

The five crankshaft main bearings are oil fed through drilled passages in the crankcase directly from the main oil gallery. Connecting rod bearings are individually fed through drilled passages in the crankshaft from main rod journals and received pressurized oil from the main bearings. The camshaft journals are fed through passages drilled vertically through the main bearing webs.

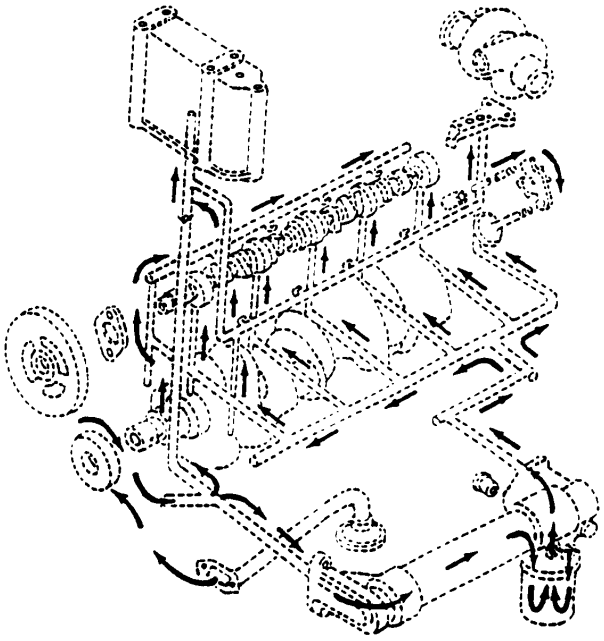
VALVE LIFTERS, PUSH RODS, ROCKER ARMS AND PISTON COOLING JETS

Tow tappet galleries, fed from the main oil gallery (through nr1 main bearing bolts holes) intersect each tappet bore to provide pressurized lube oil to the valve lifters and piston cooling jets. The valve rocker arms and push rods are lubricated via oil passing from the lifter ball socket upward through hollow push rods to rocker arms. Oil drains back to sump through holes at each end of cylinder heads under the valve covers.

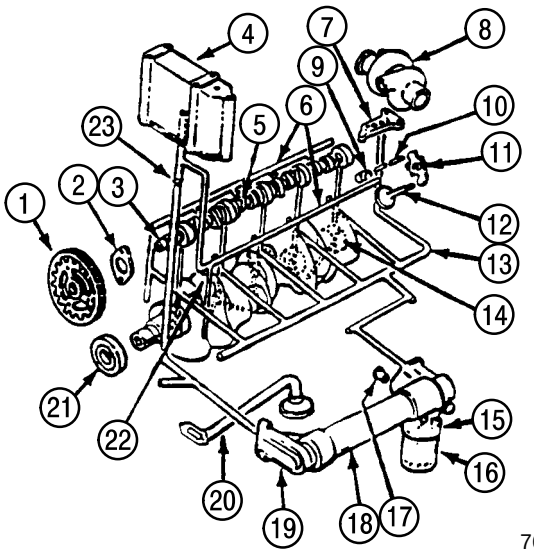
OIL RESERVOIR AND HIGH PRESSURE PUMP

The oil reservoir, used to maintain a ready supply of oil to the high pressure pump, is filled via two passages. For initial startup, oil is directed from the oil pump discharge port through a passage in the crankcase which also contains an anti–drain back check ball. This reservoir oil supply quickly replenishes oil to the high pressure pump during cold cranking to insure sufficient oil pressure to operate the injectors for quick starts. The primary reservoir oil supply is continuously fed from the left bank tappet gallery up through the front cover and discharges oil by a stand pipe near the top of the reservoir so that oil can not drain out.

Engine Lubrication System Flow Chart



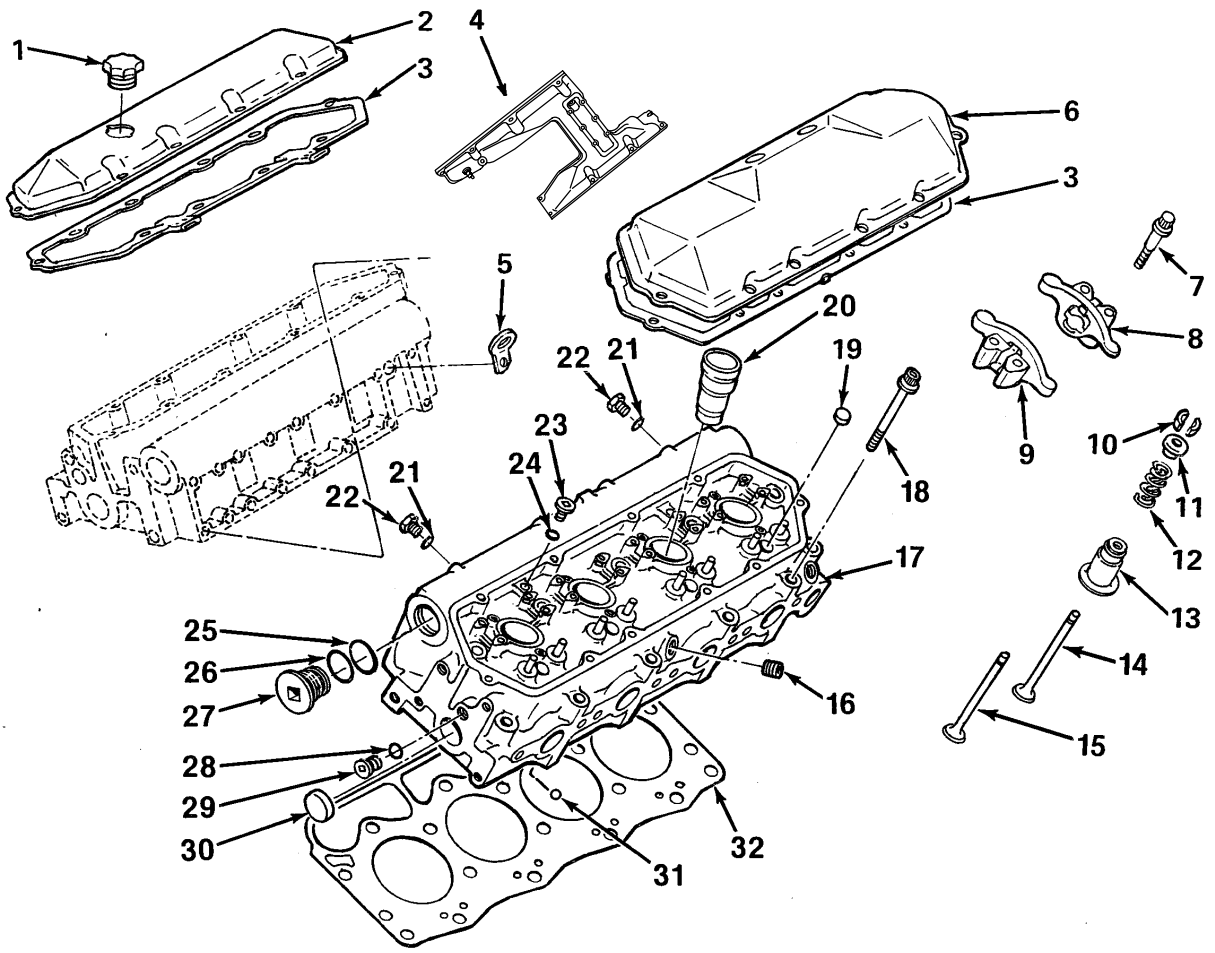
76222



76223

1 - Camshaft Gear
2 - Camshaft Thrust Plate
3 - Camshaft
4 - High Pressure Lube Oil Reservoir
5 - Piston Cooling Jets (8)
6 - Hydraulic Valve Lifter Oil Gallery
7 - Turbocharger Pedestal
8 - Turbocharger Assembly
9 - Hydraulic Valve Lifter
10- Push Rod
11- Valve Level Assembly
12- Intake/Exhaust Valve
13- Main Oil Gallery
14- Main Crankshaft Bearings
15- Oil Filter Bypass Valve
16- Oil Filter
17- Oil Pressure Regulating Valve
18- Oil Cooler
19- Oil Cooler Header
20- Oil Pick-Up Tube
21- Oil Pump
22- Connecting Rod Bearings
23- Check Valve

Cylinder Head and Valves

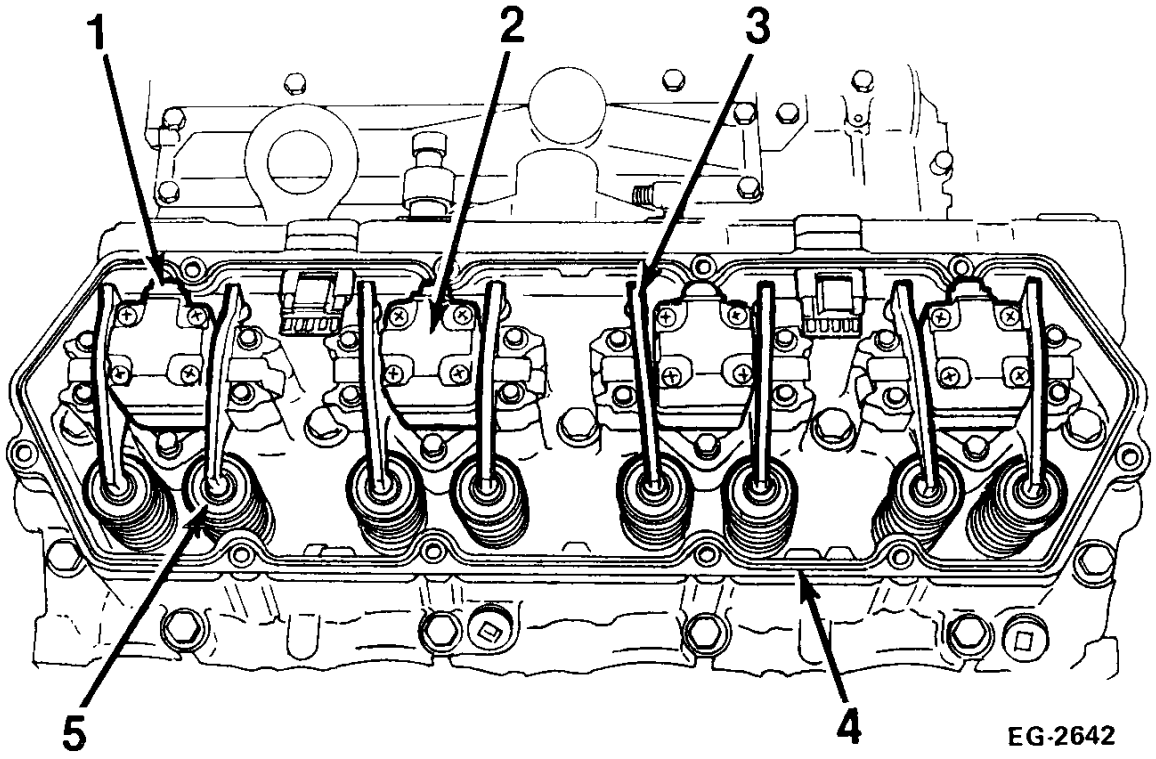


76213

Cylinder Head and Valves

1 - Oil Filler Cap
2 - R.H. Valve Cover
3 - Valve Cover Gasket (2)
4 - Intake Manifold
5 - Lifting Eye (2)
6 - L.H. Valve Cover
7 - Lever Assembly Mounting Screw (32)
8 - Intake Valve Lever Assembly (8)
9 - Exhaust Valve Lever Assembly (8)
10- Key Retainer (32)
11- Valve Rotator (16)
12- Valve Spring (16)
13- Valve Seal (16)
14- Intake Valve Stem (8)
15- Exhaust Valve (8)
16- Pipe Plug (4)
17- Cylinder Head (2)
18- Cylinder Head Mounting Bolt (36)
19- Cylinder Head Plug (8)
20- Injector Sleeve (8)
21- O-Ring (6)
22- Plug (6)
23- O-Ring Boss Plug (4)
24- O-Ring (4)
25- O-Ring (4)
26- Back-Up Supply Rail Ring (4)
27- High Press. Pump Gallery End Plug (4)
28- O-Ring (4)
29- Fuel Gallery Plug (4)
30- Plug (4)
31- Steel Ball (8)
32- Cylinder Head Gasket (2)

Cylinder Head Major Components



1 - Injector Solenoid Harness Connector (4)
2 - Injector Assembly (4)
3 - Valve Lever Assembly (8)
4 - Valve Cover Gasket
5 - Rotator (8)

Specifications

Exhaust Valves

Stem Diameter.	0.31185 – 0 .31255 in. (7.9210 – 7.9388 mm)
Stem to Guide Clearance (Max. Allowable Before Replacement)	0.0055 in. (0.140 mm)
Face to Stem Run–Out (T.I.R. Max.)	0.002 in. (0.05 mm)
Valve Face Angle	37.5°
Valve Face Margin (Min.)	0.054 in. (1.37 mm)

Intake Valves

Stem Diameter	0.31185 – 0.31255 in. (7.9210 – 7.9388 mm)
Stem to Guide Clearance (Max. Allowable Before Replacement)	0.0055 in. (0.140 mm)
Face to Stem Run–Out (T.I.R. Max.)	0.002 in (0.05 mm)
Valve Face Angle	30°
Valve Face Margin (Min)	0.066 in. (1.67 mm)

Cylinder Heads

Bore Diameter in Cylinder Head	Not Available
Valve Guide Insert (Service)	0.5634–0.5644 in. (14.310–14.336 mm)
Valve Guide O.D. (Service)	0.5648–0.5652 in. (14.346–14.356 mm)
Inside Diameter of Valve Guide Inserts (Service)	0.3141–0.3151 in.(7.978–8.004 mm)
Valve Guide Bore Finish (Micro inches)	63
Valve Guide Bore Run–Out	0.002 in. (0.05mm)
Valve Guide Taper (Max.)	0.004 in. (0.10mm)
Valve Guide Length (Service)	2.440 in. (62.08mm)
Valve Seat Width (Int. & Exh.)	0.065 – 0.095 in. (1.65 – 2.41 mm)
Valve Seat Angle (Int.)	30°
Valve Seat Angle (Exh.)	37.5°
Valve Seat Run–Out (T.I.R. Max.)	0.002 in (0.05 mm)
Valve Seat Insert O.D. (Exhaust Only)	1.7761 – 1.7771 in. (45.113 – 45.138 mm)
Valve Seat Insert I.D. (Exhaust Only)	1.449 – 1.459 in. (36.80 – 37.06 mm)
Valve Seat Insert O.D. (Intake Only)	1.7381 – 1.7391 in. (44.148 – 44.173 mm)
Valve Seat Insert I.D. (Intake Only)	1.431 – 1.441 in. (36.35 – 36.60 mm)
Valve Seat Insert Counterbore Diameter – Cylinder Head	Not Available
Gasket Surface Flatness	0.001 inches (0.025 mm) in 2 inches; 0.004 inches (0.10 mm) overall
Gasket Surface Finish (Micro inches)	63 – 125
Deck to Deck Dimension (Head Thickness Overall)	5.095 – 5.105 in. (129.41 – 129.67 mm)

Valve Head Recession Relative To Deck (Head Gasket) Surface On Cylinder Head

Intake	0.046 – 0.058 in. (1.17 – 1.47 mm)
Exhaust	0.052 – 0.064 in (1.32 – 1.63 mm)
Valve Spring	
Free Length	2.075 in. ± 0.150 in. (52.70 mm ± 3.8 mm)
Test Length	1.352 in. (34.34 mm)
Open	68–85 lbs.
Closed	225–249 lbs.

Push Rod

Run Out (Max. TIR)	0.02 in. (0.5 mm) Max.

Special Torque Values

Cylinder Head Bolt Torque	See “Special Torque Procedures”
Fuel Injector Hold Down Clamp Mounting Bolt	105 lb.in. – (12 Nm)
Fuel Injector Hold Down Clamp Shoulder Bolt	105 lb.in. – (12 Nm)
Fuel Rail End Plug	96 lb.in. – (11 Nm)
Glow Plug (See Note 1)	168 lb.in. – (19 Nm)
Oil Deflector Mounting Bolt	108 lb.in. – (12 Nm)
Oil Rail Drain Plug	50 lb.in. – (6 Nm)
Oil Rail End Plug (See Note 2)	60 lb.ft. – (81 Nm)
Valve Cover Mounting Bolt	See “Special Torque Procedures”
Valve Lever Mounting Bolt	See “Special Torque Procedures”

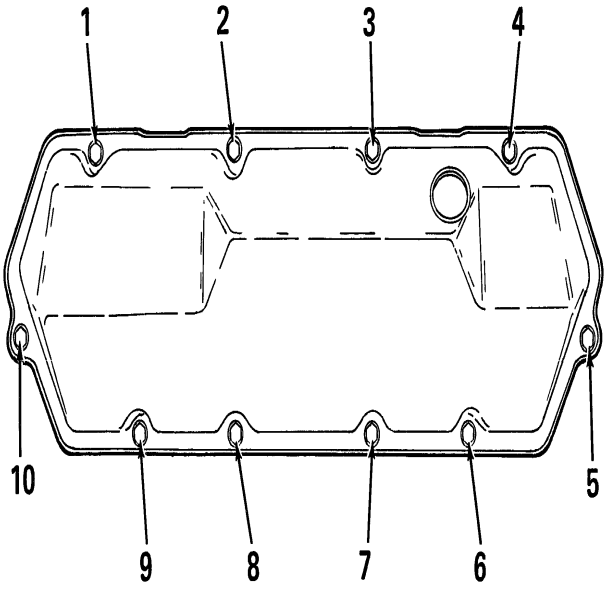
***NOTE: 1** – Apply ”Never Seez” compound (P/N 634 227 C1) to threads prior to assembly.*

***NOTE: 2** – Apply Loctite #277 to threads of bolts prior to assembly.*

Special Torque Procedures

Valve Cover Mounting Bolts

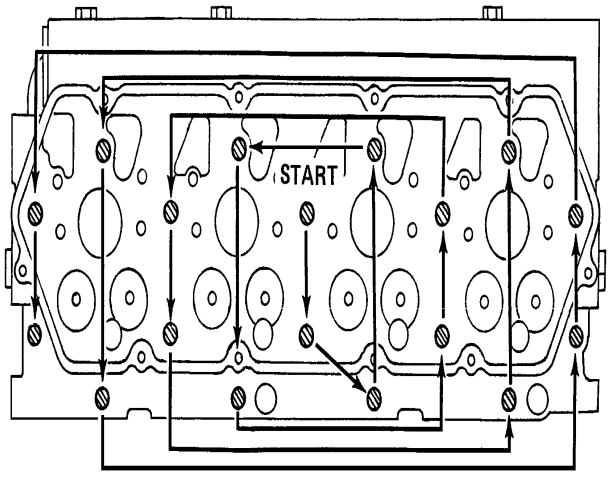
Install and tighten all valve cover mounting bolts to 97 lb-in. (11 N·m) in a line sequence as shown.



EG-1904

1. Use steps 1 and 2 to tighten cylinder head mounting bolts in a circular sequence.

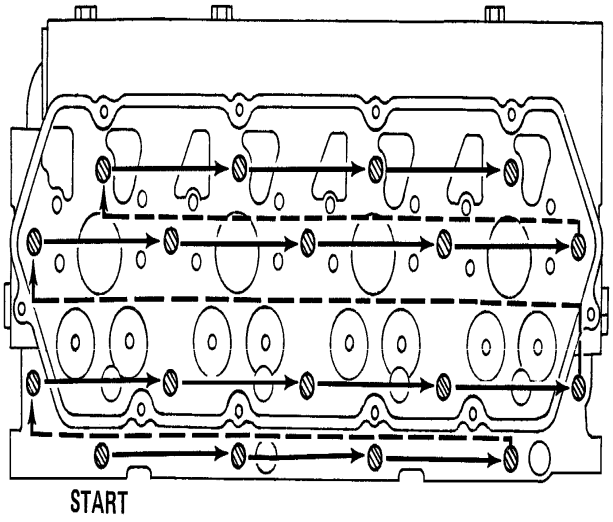
   Step 1. 65 lb.ft. (88 N·m)
   Step 2. 85 lb.ft. (115 N·m)



EG-2518

2. Use step 3 to tighten cylinder head mounting bolts in a linear sequence.

   Step 3. 105 lb.ft. (142 N·m)

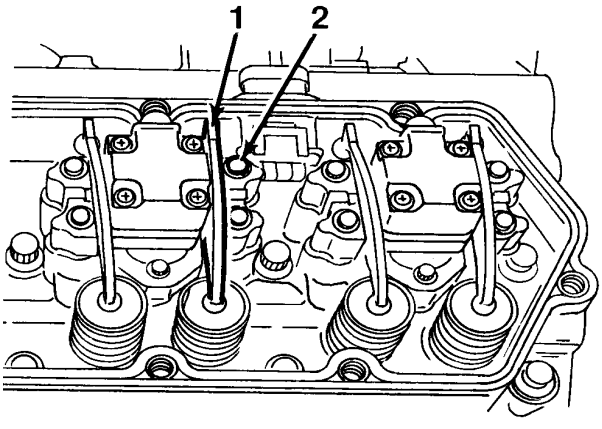


EG-2519

Valve Lever Post

Use the following procedure when positioning the timing mark for valve lever post bolt torque.

1. Rotate the crankshaft until damper notch is 15° (ATDC) from vertical. This positions all pistons below TDC, so valves do not contact pistons when tightening valve lever assemblies.
2. Tighten each pair of valve lever post bolts down EVENLY to 20 lb.ft.-(27 N·m).



EG-1562

1 - Valve Lever Assembly
2 - Valve Lever Post Bolts

Special Service Tools

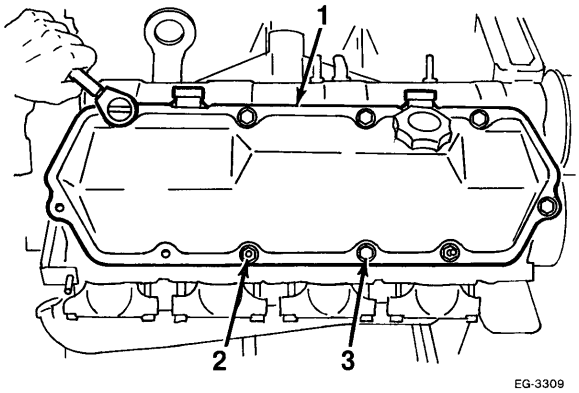
TOOLS	DESCRIPTION
ZTSE-4297	Cylinder Head Lifting Bracket
ZTSE-2482A	Compression Gauge
ZTSE-4292	Compression Gauge Adapter
ZTSE-2241	Valve Spring Tester
ZTSE-4298	Valve Spring Compressor
ZTSE-4302	Injector Sleeve Remover
ZTSE-4300	Injector/Front Seal Removal
ZTSE-4303	Injector Sleeve Installer
ZTSE-4301	Injector Tip Brush
ZTSE-4304	Injector Sleeve Brushes
ZTSE-4305	Injector Sleeve Seat Brush
ZTSE-4308	Cylinder Head Coolant Plate
ZTSE-43862	Cylinder Head Bolt Bottom Tap
ZTSE-1879	Slide Hammer 5/8 inch (16 mm)
ZTSE-4299	Injector Holder Rack and Caps
ZTSE-4320	Cleaning Brush Set
ZTOEM-4263	Slide Hammer 1/2 inch (13 mm)
ZT-8006	Slide Hammer Adapter 5/8 inch (16 mm) to 1/2 inch (13 mm)
ZTSE-4354	Injector Remover
ZTSE-4353	Injector Installer
OEM-1272	Dye Penetrant Kit

Cylinder Head

Cylinder Head Disassembly

VALVE COVER REMOVAL - RIGHT VALVE COVER

1. Remove all items that are attached to the valve covers.
2. Remove two (2) stud nuts and eight (8) valve cover mounting bolts. Remove valve cover.

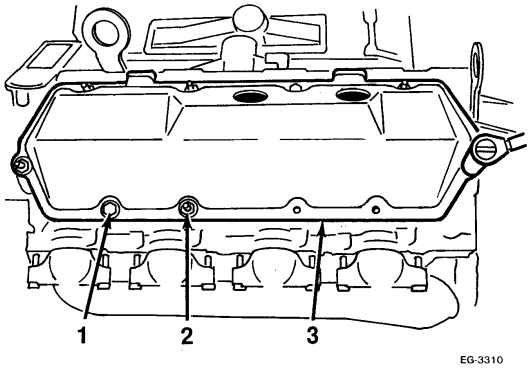


1 - Valve Cover
2 - Nut
3 - Valve Cover Mounting Bolt

3. Remove right valve cover from cylinder head.

VALVE COVER REMOVAL - LEFT VALVE COVER

1. Before left valve cover can be removed, the following parts must first be taken off:
   a. Crankcase breather elbow.
   b. Crankcase breather assembly.
2. Remove two (2) stud nuts securing glow plug relay bracket to valve cover.



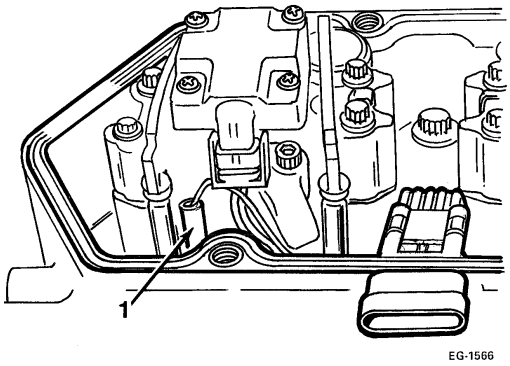
1 - Valve Cover Mounting Bolt
2 - Valve Cover Mounting Stud Nut
3 - Valve Cover

3. Remove the remaining four (4) stud nuts and three (3) valve cover mounting bolts.

VALVE COVER GASKET REMOVAL

NOTE: *Before valve cover gasket can be removed, all electrical wiring must be disconnected as follows:*

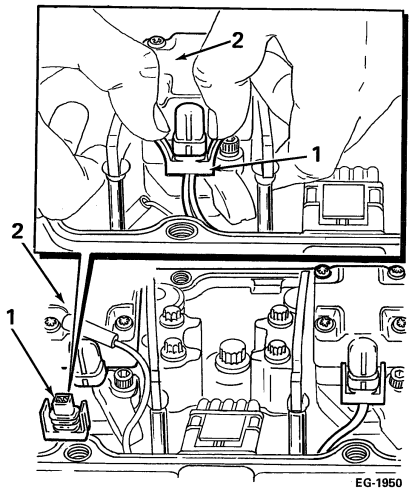
1. Disconnect wiring harness from valve cover gasket (at two locations).
2. Remove four (4) glow plug leads.



1 - Glow Plug Leads

IMPORTANT: <u>Do</u> <u>Not</u> pull on wires.

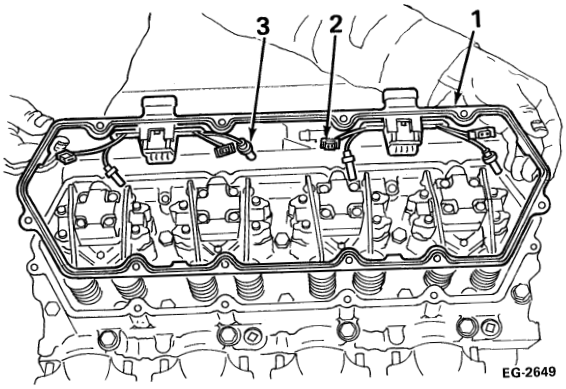
3. Disconnect four (4) clip style injector solenoid harness connectors from injector solenoids by spreading tabs and pushing down.



1 - Injector Solenoid Harness Connector
2 - Injector Solenoid
3 - Fuel Injector

IMPORTANT: <u>Do Not</u> not spread tabs out to far as they may crack or break off connector.

4. Remove valve cover gasket with under valve cover harness.

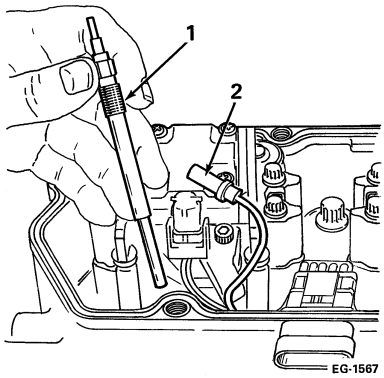


1 - Gasket With Under Valve Cover Harness
2 - Injector Solenoid Harness Connectors
3 - Glow Plug Leads

NOTE: *Valve cover gasket is reusable.*

GLOW PLUG REMOVAL

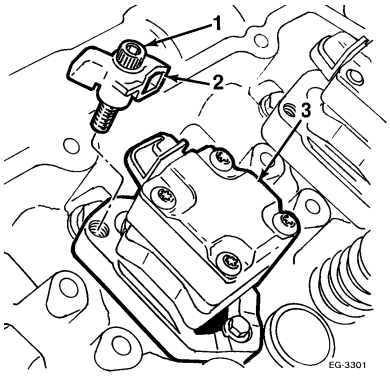
1. Using a 10 mm deep socket, remove four (4) glow plugs [per head].



1 - Glow Plug
2 - Glow Plug Lead

OIL DIRECTOR REMOVAL

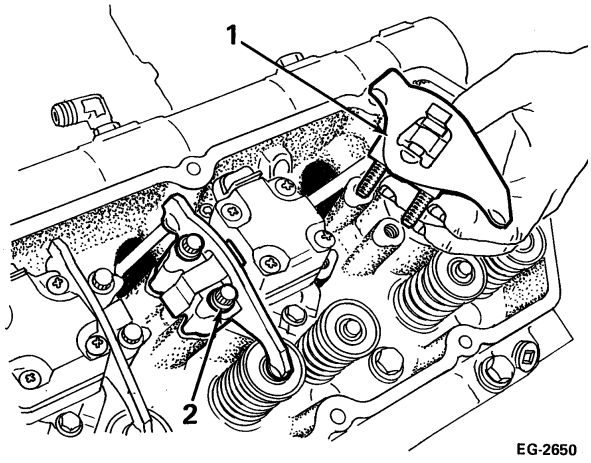
1. Remove the four (4) oil director spouts.



1 - Oil Director Spout Mounting Bolt
2 - Oil Director
3 - Fuel Injector

VALVE [ROCKER] LEVER REMOVAL

1. Remove valve lever mounting bolts.
2. Lift valve lever assembly from head.



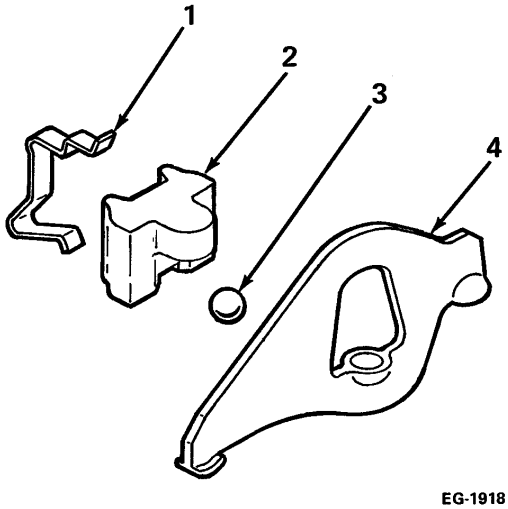
1 - Valve Lever Assembly
2 - Valve Lever Mounting Bolt

NOTE: *Intake and Exhaust valve lever assemblies are different. Mark each location to allow for correct installation.*

VALVE LEVER DISASSEMBLY

Disassemble valve lever assembly as follows:

1. Using caution, remove valve lever clip securing valve lever, valve lever post and 3/8 inch (10 mm) chrome ball together.



1 - Valve Lever Clip
2 - Valve Lever Post
3 - Chrome Ball
4 - Valve Lever

IMPORTANT: Be sure to place chrome ball into a container to prevent loss.

2. Remove 3/8 inch (10 mm) chrome ball from cup on valve lever.
3. Separate valve lever from valve lever post.

Valve Lever Cleaning and Inspection

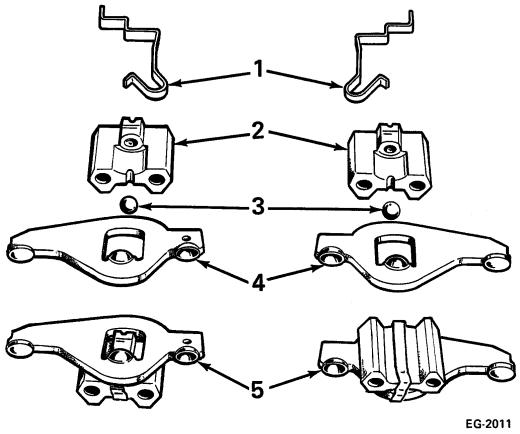
Clean all parts with a suitable solvent use filtered compressed air to dry the parts.

Inspect valve tips and corresponding valve lever pads for pitting or scuffing. Inspect ball and ball sockets in lever for scuffing. Replace levers as required.

Inspect lever post ball socket for excessive wear. Inspect bolts for thread damage, replace worn components as required.

VALVE LEVER REASSEMBLY

1. Reassemble valve lever assembly component parts as follows:



EG-2011

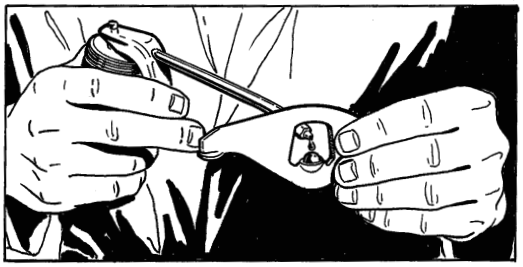
1 - Retaining Clip
2 - Valve Lever Post
3 - Chrome Ball
4 - Valve Lever
5 - Valve Lever Assy. (Two Views)

Step 1. Place chrome ball on valve lever cup and lubricate with clean engine oil.

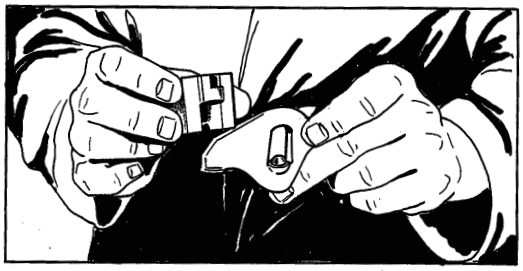
Step 2. Place valve lever post on chrome ball.

Step 3. Snap retaining clip over valve lever post groove.

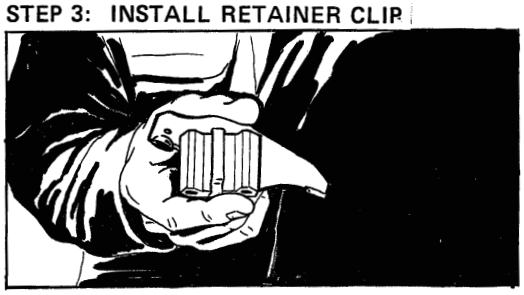
STEP 1: LUBRICATE CHROME PIVOT BALL



STEP 2: INSTALL VALVE LEVER POST

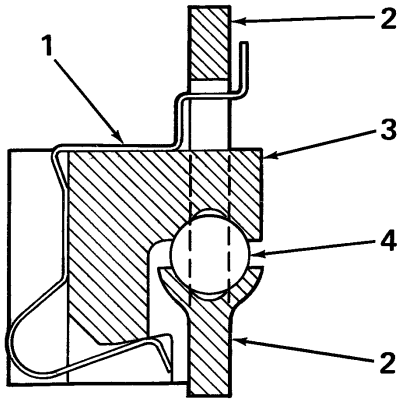


STEP 3: INSTALL RETAINER CLIP



EG-2014

NOTE: *Check that retaining clip is installed correctly.*



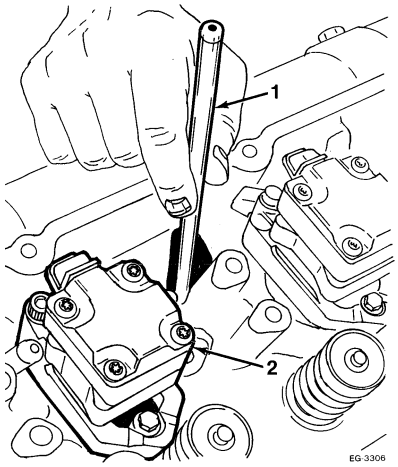
FRONT VIEW

EG-1790

1 - Retaining Clip
2 - Valve Lever
3 - Valve Lever Post
4 - Pivot Ball

PUSH ROD REMOVAL

1. Remove push rods and identify each so they are returned to their original positions during installation.



1 - Push Rod
2 - Fuel Injector

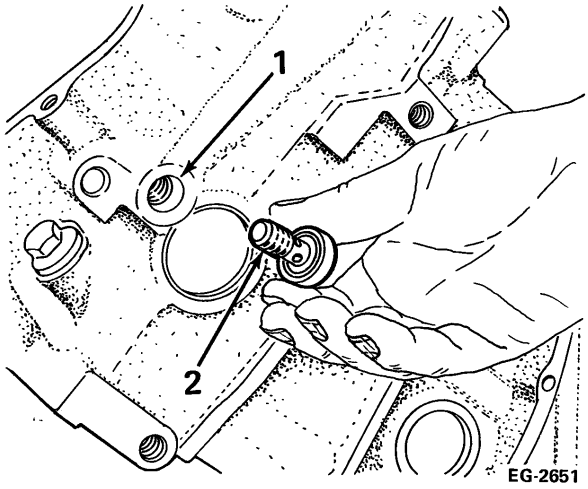
DRAIN CYLINDER HEADS AND HIGH PRESSURE PUMP RESERVOIR

⚠WARNING

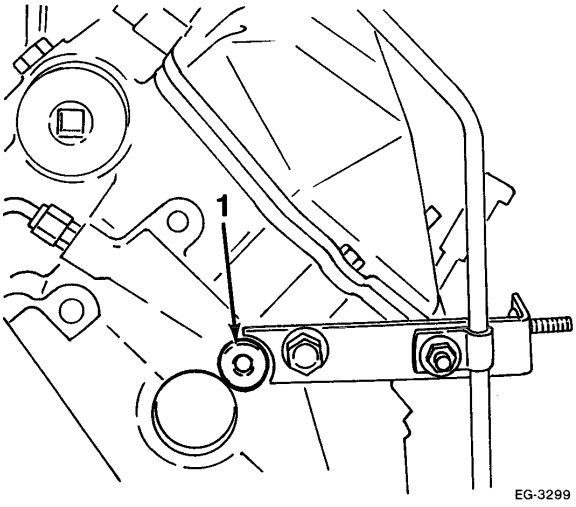
BEFORE PERFORMING THIS PROCEDURE, BE SURE THE HIGH PRESSURE PUMP RESERVOIR AND ITS HYDRAULIC LINES HAVE BEEN DRAINED OF OIL. IF THE HIGH PRESSURE PUMP IS STILL MOUNTED TO THE FRONT COVER, REFER TO SECTION 10 FOR FURTHER INFORMATION.

IMPORTANT: The fuel rails, oil rails and high pressure pump reservoir must be drained prior to removing the injectors to prevent leakage into the cylinder bore.

1. Drain fuel galleries by removing O-Ring plugs at each end of both cylinder heads

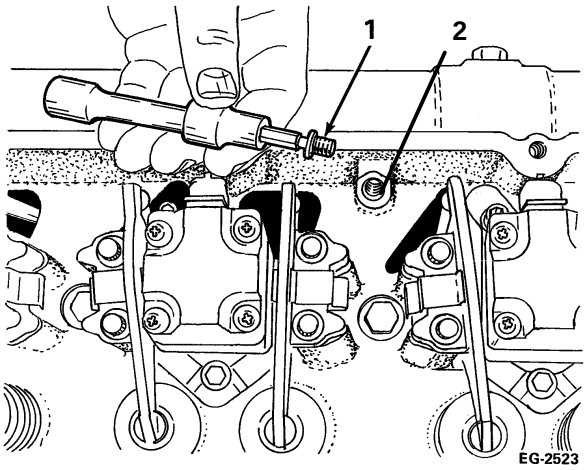


1 - Fuel Galley Port
2 - Fuel Galley Drain Plug



1 - Fuel Gallery Drain Plug

2. Drain oil galleries by removing four (4) O-Ring plugs located under valve cover.

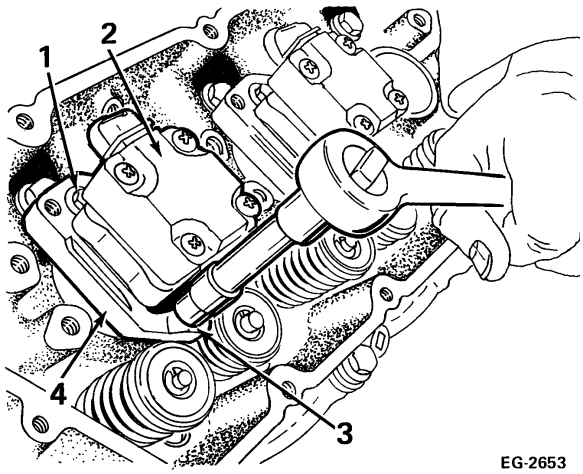


1 - Oil Gallery Drain Plug
2 - Oil Gallery Drain Plug Port

INJECTOR REMOVAL

NOTE: *Injectors can be removed with valve rocker levers in place.*

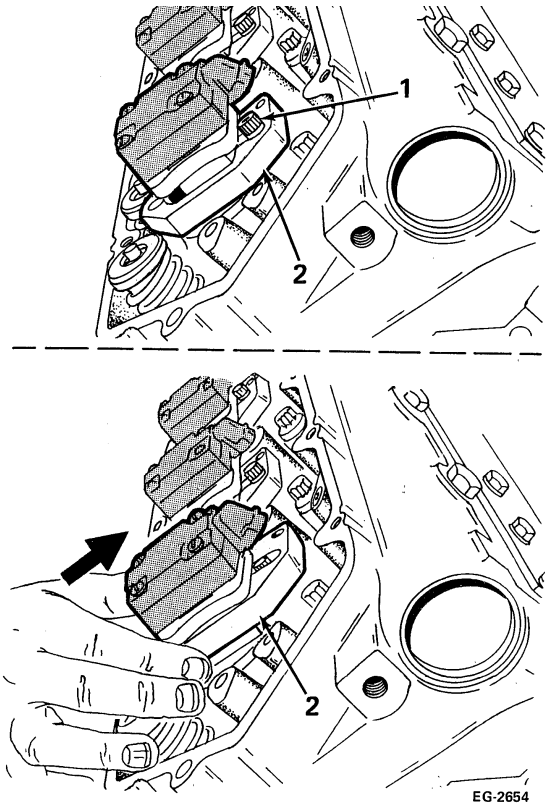
1. Remove all outboard (exhaust side) injector hold down clamp mounting bolts securing injectors.



1 - Shoulder Bolt
2 - Fuel Injector
3 - Hold Down Clamp Bolt
4 - Hold Down Clamp

NOTE: *Shoulder bolt on inboard side is not accessible and does not require removal.*

2. Disengage injector hold down clamp from shoulder bolt by sliding clamp upward away from valve springs, then, up and over head of shoulder bolt.

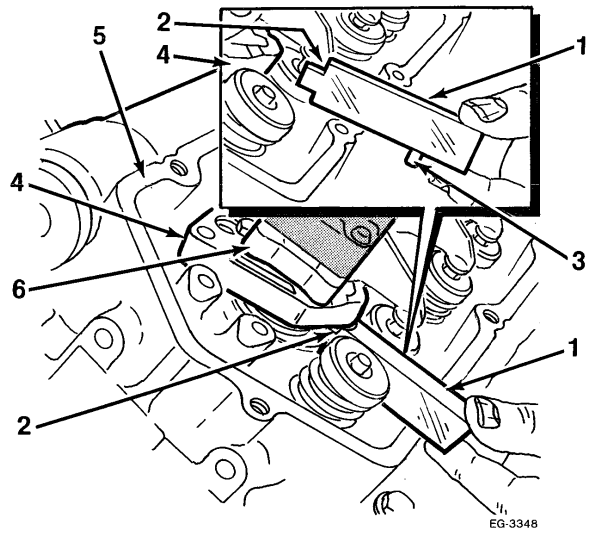


1 - Shoulder Bolt
2 - Hold Down Clamps

NOTE: *The shoulder bolt on the inboard side does not have to be removed.*

3. Remove fuel injector as follows:

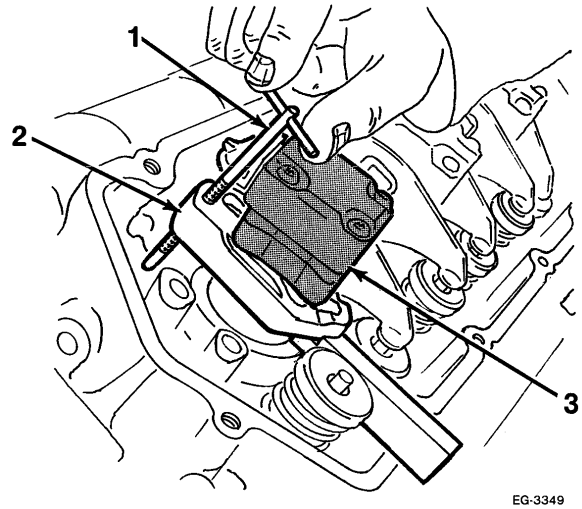
   a. Install injector removal tool **ZTSE4354** under hold down clamp.



1 - Removal Tool
2 - Removal Tool Lip
3 - Stub
4 - Hold Down Clamp
5 - Cylinder Head
6 - Fuel Injector

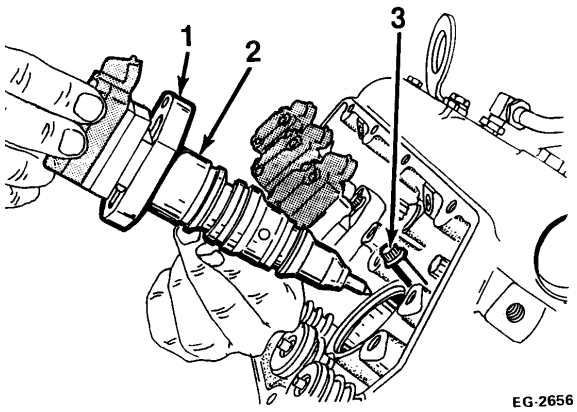
IMPORTANT: Be sure the lip of the removal tool slides under hold down clamp and stub of tool is braced against the cylinder head wall.

4. Install “T” screw into hold down clamp and turn screw until fuel injector is unseated.



1 - “T” Screw
2 - Hold Down Clamp
3 - Fuel Injector

5. Lift injector straight up and out of injector bore, taking care not to damage O-Rings.

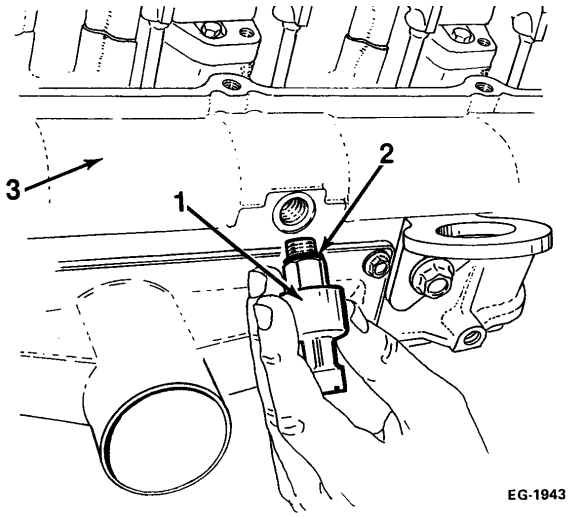


1 - Hold Down Clamp
2 - Fuel Injector
3 - Shoulder Bolt

6. If required, remove four (4) shoulder bolts.

SENSOR REMOVAL

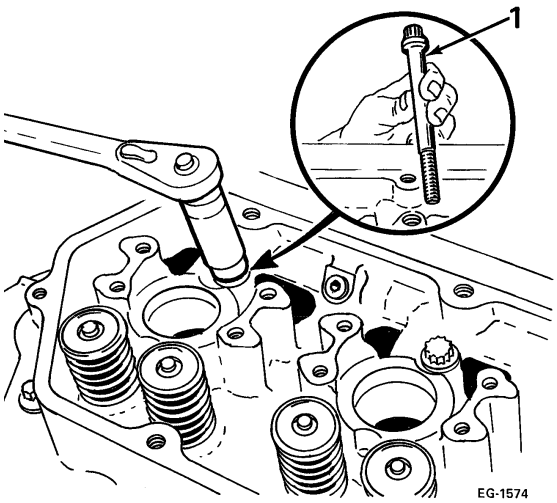
1. Remove Injection Control Pressure sensor together with O-Ring from left front cylinder head (inboard side). Discard O-Ring and replace with new.



1 - Injection Control Pressure Sensor
2 - O-Ring
3 - Left Cylinder Head

CYLINDER HEAD REMOVAL

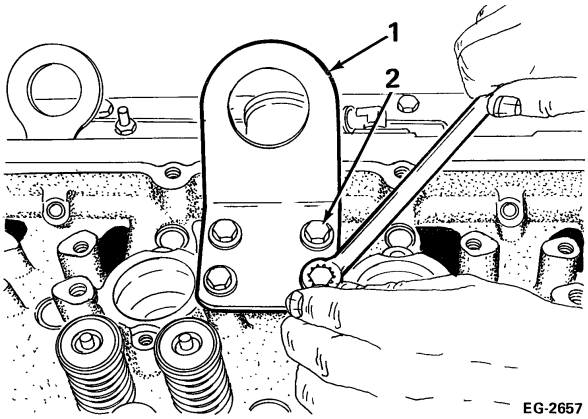
1. Remove the eighteen (18) cylinder head bolts.



1 - Flange Head Cylinder Head Mounting Bolt

NOTE: *The cylinder head bolts are the flange head type which do not require washers. All head bolts are the same length.*

2. Attach lifting bracket **ZTSE4297** to cylinder head using four (4) lifting bracket mounting bolts. Locate bracket in the center of the head.

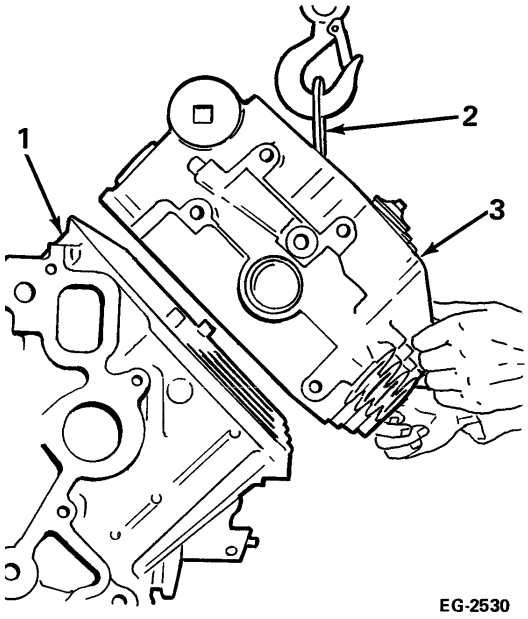


1 - Cylinder Head Lifting Bracket
2 - Lifting Bracket Mounting Bolts

IMPORTANT: Be sure cylinder head lifting bracket is mounted in the center of the cylinder head.

NOTE: *Lifting bracket allows cylinder head to lift squarely with crankcase.*

3. Install a suitable lifting sling to lifting bracket and carefully remove each cylinder head.



1 - Crankcase
2 - Lifting Bracket
3 - Cylinder Head

4. Remove cylinder head gasket. Be careful not to damage cylinder head locating dowel sleeves.

Cylinder Head Cleaning

1. With valves installed to protect the seats, remove deposits and gasket material from valve heads and gasket surface with a scraper and wire brush. **BE CAREFUL NOT TO DAMAGE CYLINDER HEAD GASKET SURFACE.**
2. Use a suitable solvent to remove dirt grease and other deposits; clean all bolt holes; be sure gasket surfaces, oil return and water passages are clean. Blow out with filtered compressed air.

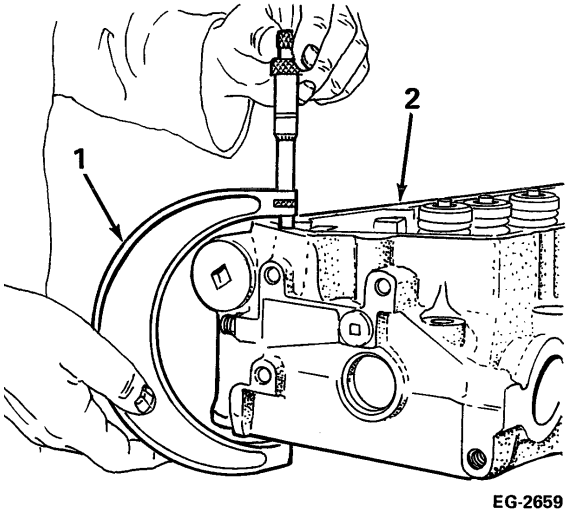
NOTE: *Make sure crankcase threads and cylinder head bolts are clean. DIRT IN THREADS OR DAMAGED THREADS MAY CAUSE BINDING AND RESULT IN A FALSE TORQUE READING. Use bottoming tap (ZTSE-43862) (Metric) to clean each tapped hole in crankcase top deck. Then remove debris from holes with filtered compressed air.*

Cylinder Head Inspection

NOTE: *Cylinder head condition must be evaluated by inspecting for warpage, thickness, cracks or valve leakage.*

CHECK FOR THICKNESS

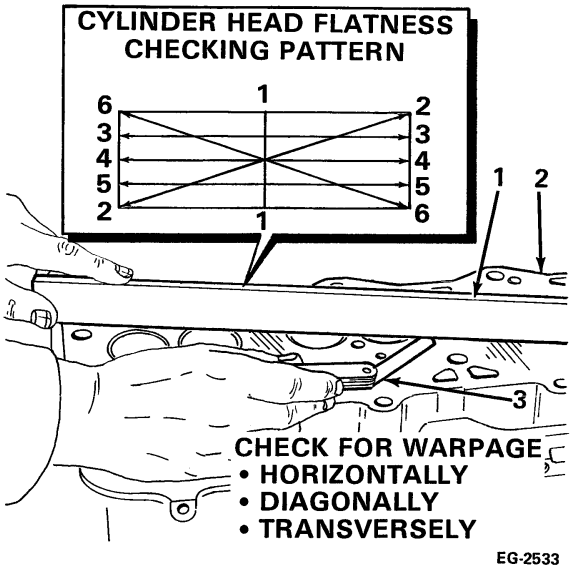
1. Remove mounting hardware securing air intake covers to cylinder head.
2. To determine if cylinder head has previously been resurfaced, use an outside micrometer and measure cylinder head thickness at all four corner locations. If minimum specification is not met, replace the head. (Refer to **SPECIFICATIONS.**)



1 - Micrometer
2 - Cylinder Head

INSPECT FOR WARPAGE

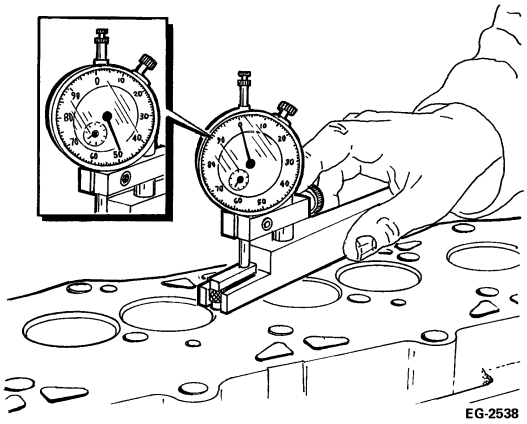
Using a straightedge and feeler gauge, check the cylinder head gasket surface for warpage utilizing the checking pattern. Replace cylinder head if beyond specified limits. (See **SPECIFICATIONS**)



1 - Straightedge
2 - Cylinder Head

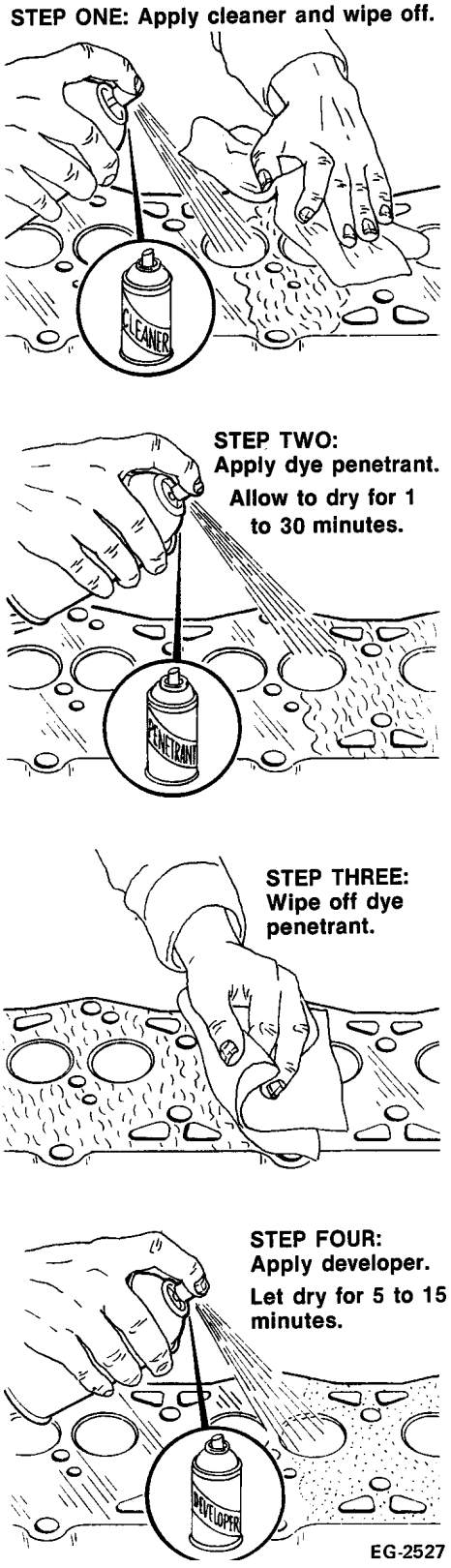
IMPORTANT: Replace cylinder head if any one of the inspection criteria does not meet specifications. Cylinder heads cannot be resurfaced, because removal of bottom deck material will result in piston to valve contact.

3. Prior to valve removal, check valve head recession (Relative to deck) as follows: [Intake & Exhaust]
   a. Set surface gauge on cylinder head deck and zero the dial indicator.
   b. Move dial indicator onto the valve and record the reading.
   c. Refer to specifications for intake and exhaust valve recession. If out of specifications, valve and valve seat require replacement.



INSPECT FOR CRACKS (USING DYE PENETRANT METHOD OEM - 1272)

Visually inspect for cylinder head cracks using the four step dye penetrant method as follows:



STEP ONE - Spray the cleaner onto the lower deck (gasket surface) of the head and wipe dry.

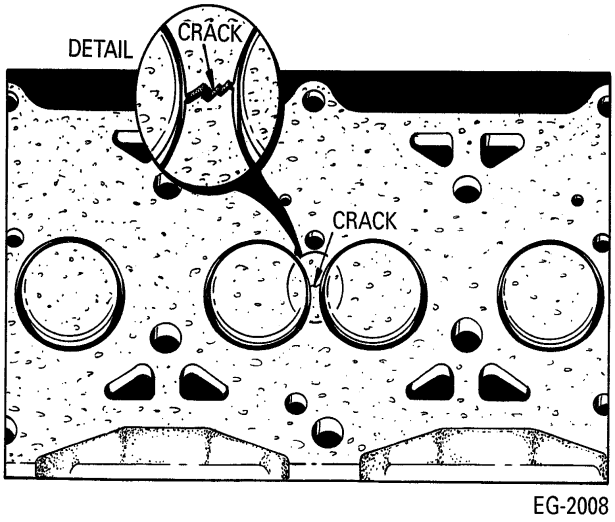
STEP TWO - Spray on the dye penetrant. Allow the dye to remain on the surface from one to thirty minutes.

STEP THREE - Wipe the dye off the surface.

NOTE: *Dye will remain in any cracks during the "wipe off" step.*

STEP FOUR - Spray on the developer and let dry for five to fifteen minutes.

NOTE: *Cracks will show up as purple lines against the white developer.*



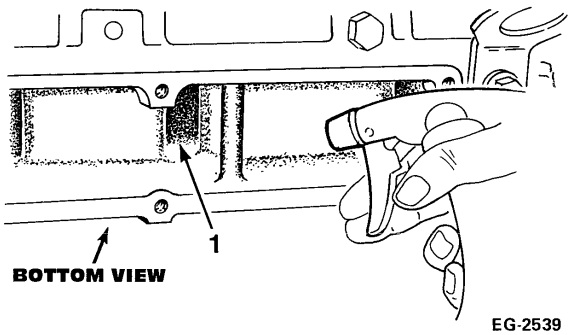
IMPORTANT: If any cracks are present, replace the cylinder head.

CHECK FOR VALVE LEAKAGE (USING MINERAL SPIRITS)

Visually inspect for valve leakage as follows:

Position the cylinder head on wood blocks with the gasket surface facing down.

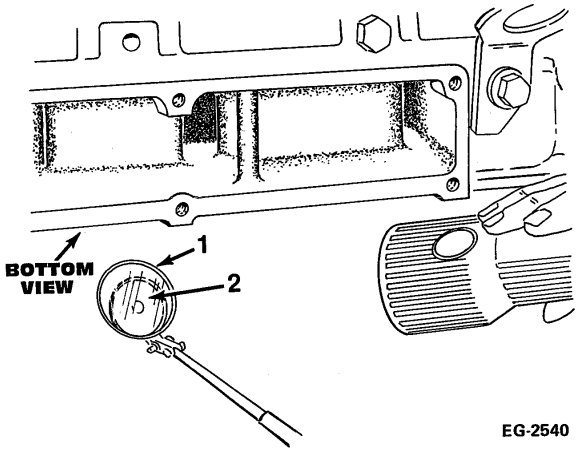
Squirt mineral spirits into the valve ports.



1 - Valve Ports

Wait five minutes, using an inspection mirror and light, visually inspect the valve perimeter area for leakage of the mineral spirits. Check all intake and exhaust valve ports.

IMPORTANT: There should be no leakage. reconditioning is not required if the cylinder head passes the mineral spirits test. if leakage is observed, the valves require reconditioning. Refer to "cylinder Head Reconditioning" in this section. This test does not check for condition of valve guide or valve stem-to-guide clearance

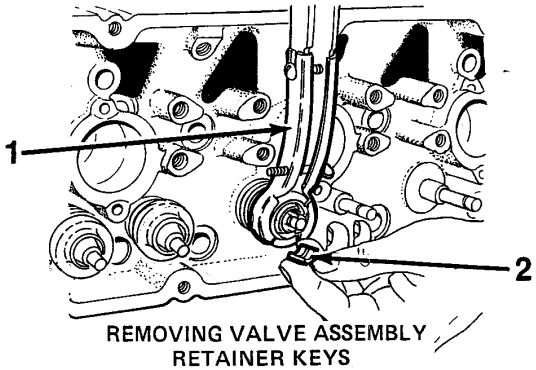


1 - Mirror
2 - Valve

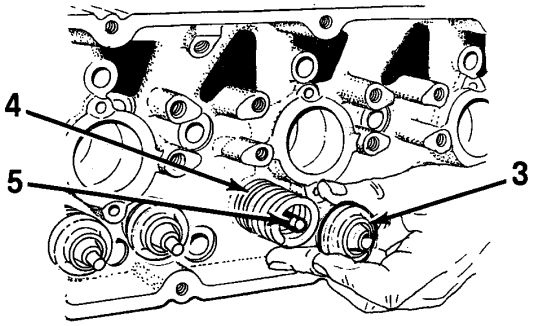
Cylinder Head Reconditioning

VALVE DISASSEMBLY

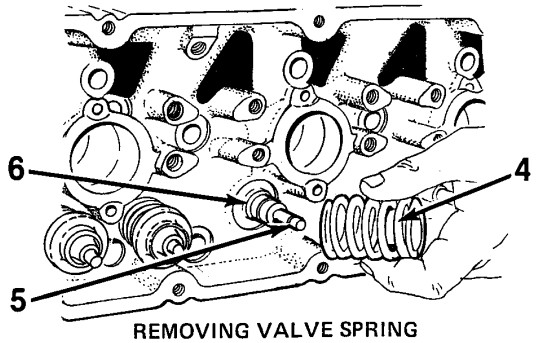
1. Remove valves from cylinder head as follows:



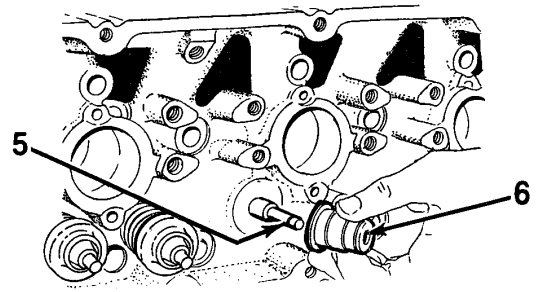
REMOVING VALVE ASSEMBLY RETAINER KEYS



REMOVING VALVE CAP



REMOVING VALVE SPRING



REMOVING VALVE SEAL EG-3528

1 - Valve Spring Compressor Tool
2 - Retainer Keys
3 - Rotator
4 - Valve Spring
5 - Valve Stem
6 - Valve Seal

a. Using valve spring compressor **ZTSE-4298** compress valve springs and remove retainer keys.

b. Remove valve rotator.

c. Remove valve spring.

d. Push down on valve stem and remove valves seal.

e. Remove valve.

IMPORTANT: Keep valves and their related parts together so they may be installed in their respective positions.

f. Repeat steps a thru e for each valve.

NOTE: *If valve does not slide out easily, inspect valve stem for burrs. If a burr is present, remove it to prevent valve guide damage. Keep valves in order so they can be reinstalled into their original positions.*

Valves

Cleaning

1. Remove all carbon from valve stems and valve heads using a suitable solvent and a fine brass wire brush.

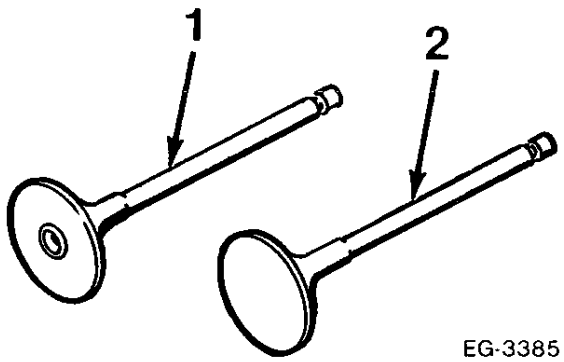
Inspection

1. Visually inspect each valve, replacing any that show evidence of burn marks, warpage, scuffing or bending.
2. Measure each valve stem for wear using micrometer to measure valve stem diameter. Record readings.
3. Using the valve stem diameter and valve guide inside diameter measurements, determine valve stem-to-guide running clearance. Refer to "Specifications**"**. Replace valve or valve guide as required.

REFACE VALVES

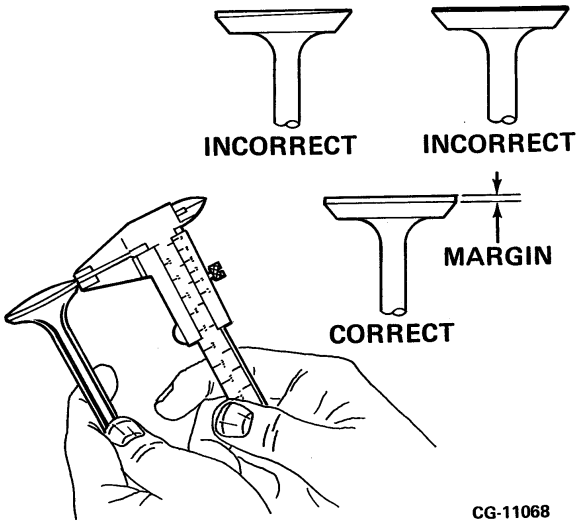
NOTE: *If valves are in a serviceable condition, reface the valve to the specified angle, as required.*

IMPORTANT: Intake and exhaust valves have the same stem length and diameter, however, the intake valve has a dimple located on the bottom of the valve while the exhaust valve is unmarked.



1 - Intake Valve With Dimple
2 - Exhaust Valve

1. Reface the valves as follows:
   a. Dress cutting stone prior to refacing valves, using dressing stud attachment or grinder.
   b. Install valve in grinder and set to specified angle.
   c. Grind valve face. Remove only minimum amount of material necessary to true valve face.
2. Measure valve face margin at four locations using a caliper.



NOTE: *An insufficient margin will not provide proper heat dissipation and lead to warpage or breakage.*

VALVES GUIDES

Cleaning

1. Using a nylon brush, soap and water, clean valve guide bores in cylinder head.
2. Blow out any residue with filtered compressed air.

Inspection

1. Using an appropriate valve guide bore gauge or a telescoping gauge and micrometer, check for proper guide bore diameter. Refer to valve guide bore diameter dimensions in “Specifications”.
2. Replace guides having bore diameters, tapers and/or run-out beyond specified limits.

Valve Seats

Cleaning

1. Clean valve seat area using suitable solvent, prior to visual inspection.

Inspection

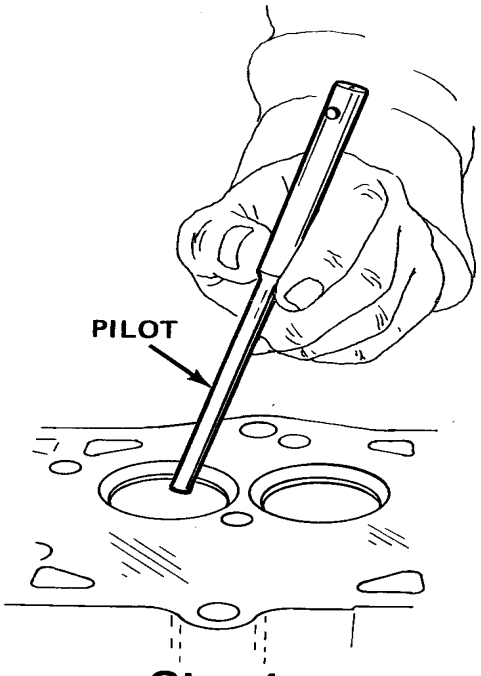
1. Visually inspect the exhaust valve seats for wear, burned or cracked condition. These conditions require valve seat replacement.

Valve Seat Resurfacing

1. Resurface valve seat as follows:
   a. Lightly lubricate and install correct size pilot into valve guide bore.
   b. Choose correct angle grinding stone and dress stone. Refer to “Specifications” for valve seat angles.
   c. Install grinding stone over pilot.
   d. Lower grinder head over pilot shank until wheel barely clears the valve seat. Turn on power. **GENTLY** apply grinding wheel to valve seat with little pressure other than weight of the wheel.
   e. Raise wheel frequently to prevent over- heating.
   f. Grind seat to a smooth even surface.

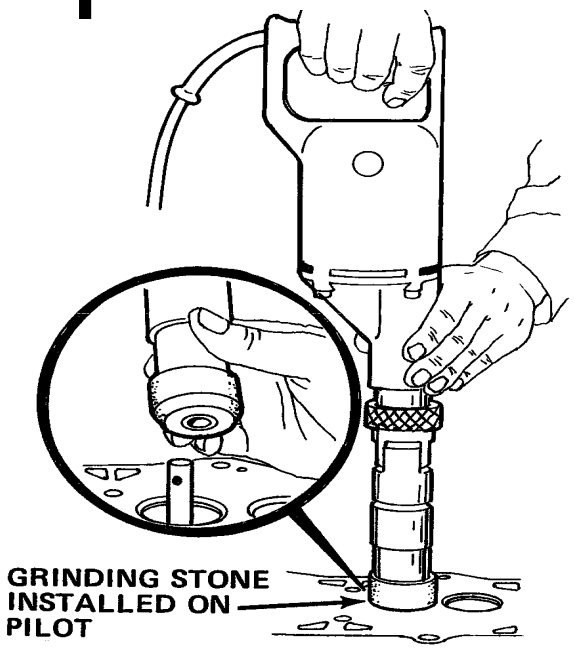
Replacement Valve Seats

NOTE: *Replacement valve seats are available.*



Step 1

INSTALL PILOT IN VALVE GUIDE.

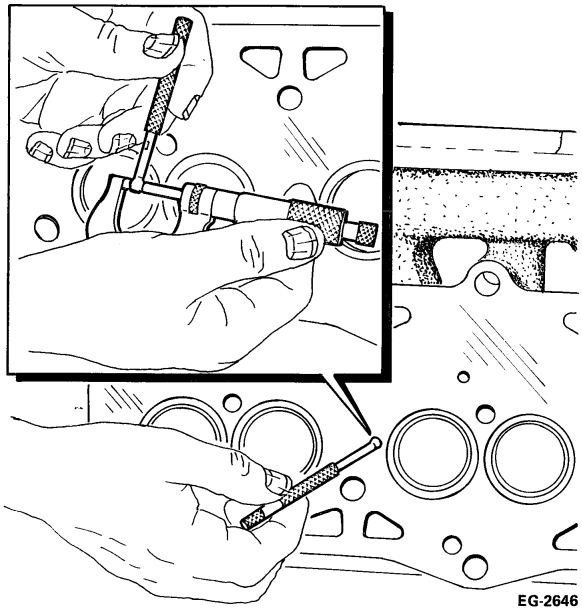


Step 2

- REMOVE "T" HANDLE
- INSTALL DRESSED STONE OVER PILOT AND GRIND SEAT.
- AFTER GRINDING, REMOVE STONE AND PILOT.
- CLEAN SEAT SURFACE.

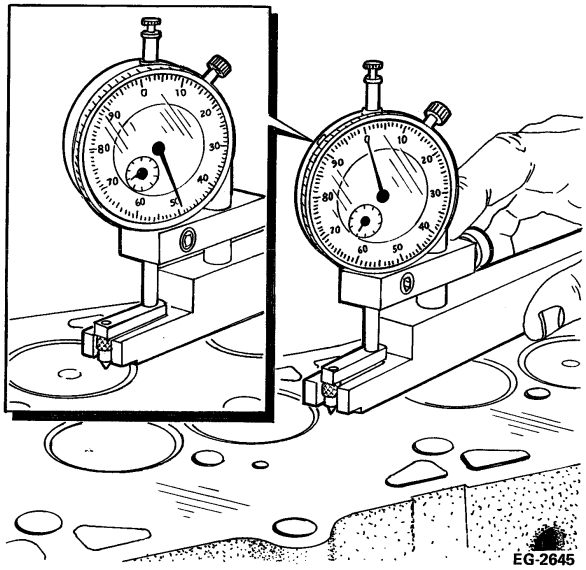
EG-2643

2. After grinding, check valve seat width using a dial caliper. Refer to **"SPECIFICATIONS"** for seat width limits. If seat widths are excessive, they may be corrected by grinding with a 15 degree smaller angle stone.



IMPORTANT: If a new valve will not correct an excessive recession condition, a valve seat must be installed. If the valve face protrudes above the deck, the valve seat will have to be reground deeper into the head.

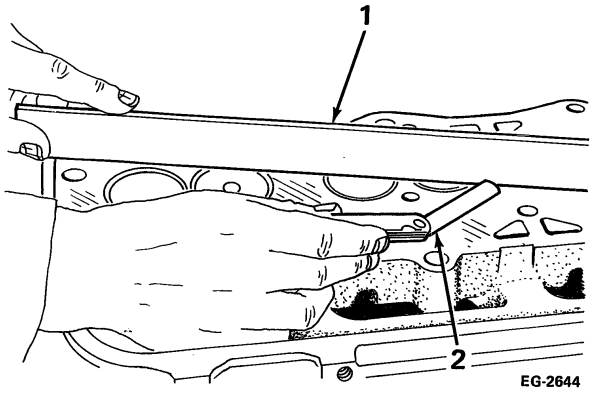
3. After grinding valve seat, check seat for recession using a depth gauge and micrometer. Valve seat recession should not exceed limits shown in **"SPECIFICATIONS"**.



4. After resurfacing valves and seats, insert valves in clean valve guide and check valve face contact with valve seat using Prussian Blue™ as follows:
   a. Spread thin film of Prussian Blue™ on valve face. Insert valve into its guide.
   b. Apply pressure on exact center of valve head while making a quarter turn in the seat.
   c. Remove valve, inspect impression made on seat and on valve face.
   d. Bluing should appear around entire contact surface of valve face and valve seat to be acceptable. **CHECK SEVERAL TIMES TO PREVENT ERROR**. If acceptable, proceed with valve installation.
5. It is important to have the finished seat face contact the approximate center of valve face. Position valves in cylinder head. Place a thin coat of Prussian Blue™ on each valve face and tap valve lightly to its seat. Refer to valve resurfacing in this section for instructions for proper use of Prussian Blue™.

NOTE: *This is merely for test and proof of results of refacing and reseating operations. A poor grind job cannot be corrected by lapping. Inspect each valve for seat dimensions as outlined in specifications and make any necessary corrections. Corrections should always be made on the seat and not valve face.*

Valve recession may be checked by using a straightedge and feeler gauge or surface gauge. Refer to **"SPECIFICATIONS"** for recession limits. If recession is excessive install a new valve. If the valve protrudes above the deck, regrind the valve seat.



1 - Straightedge
2 - Feeler Gauge

Valve Springs

CLEANING

1. Clean all valve springs and seats in a suitable solvent.

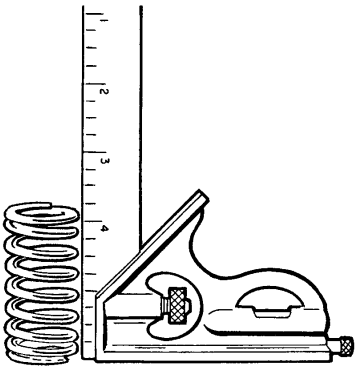
INSPECTION

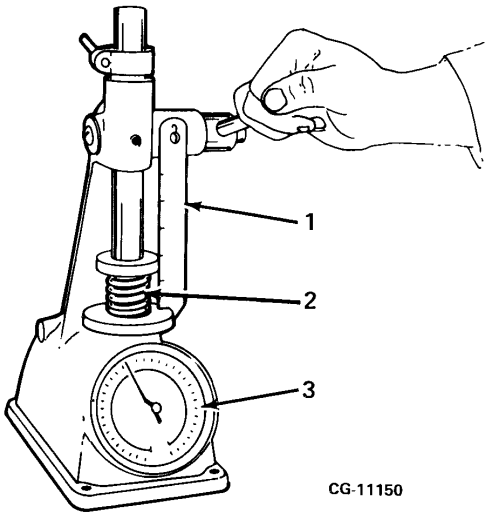
1. Visually inspect valve spring for rust, pitting and cracks. Look for spring distortion.
2. Spring ends must be flat and square to prevent lateral loads on valve stem.

NOTE: *Out of square springs place a side load on the stem causing rapid guide wear.*

3. Refer to **"SPECIFICATIONS"** and test:

   Valve spring free length.
   Valve spring length under load. Use spring tester **ZTSE2241**.





1 - Scale
2 - Valve Spring
3 - Load Indicator

4. Replace any spring assembly which fails visual or functional inspection.

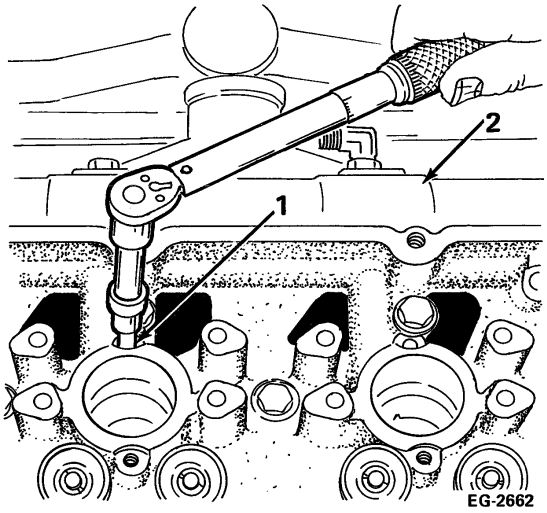
VALVE KEEPERS

1. Visually inspect inside for shearing and outside of keepers for wear.
2. Replace any worn keepers in pairs, as required.

Cylinder Head Pressure Test

Use the following steps to perform cylinder head pressure test.

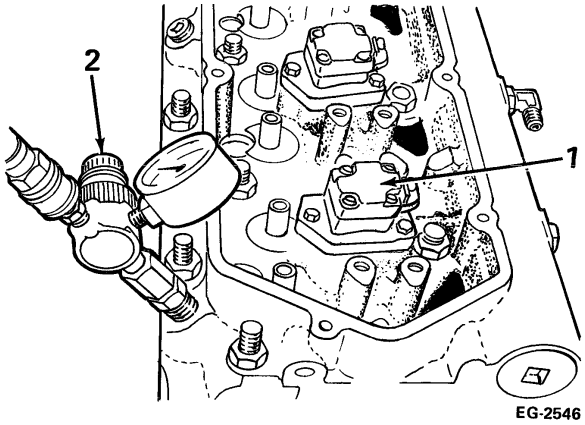
1. If removed, install shoulder bolt into cylinder head. Tighten to special torque value.



1 - Shoulder Bolt
2 - Cylinder Head

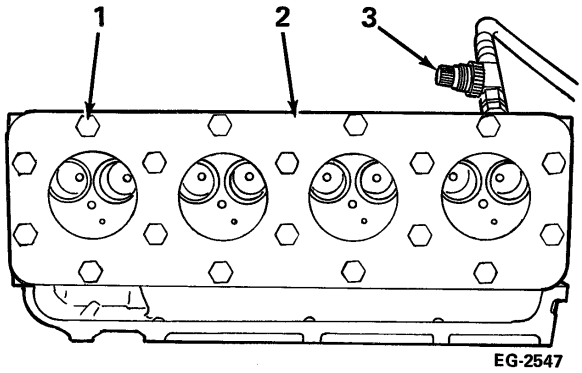
2. Install fuel injectors into cylinder head injector bores and secure. Tighten to special torque value.

3. Remove fitting or plug from cylinder head and install pressure test regulator/gauge assembly.



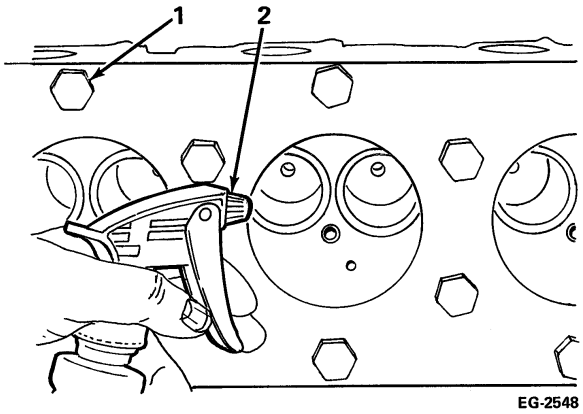
1 - Fuel Injector
2 - Pressure Regulator/Gauge

4. Install cylinder head pressure plate on gasket side of cylinder head. Secure plate to cylinder head using eighteen (18) mounting bolts.



1 - Pressure Plate Mounting Bolts (18)
2 - Pressure Plate
3 - Pressure Gauge and Regulator

5. Spray a soapy water mixture into valve bores. Apply air pressure and adjust to 18 - 20 psi (124-138 kPa) and visually inspect for leaks at the following:
   a. Ports
   b. Upper cylinder head deck
   c. Lower cylinder head deck
   d. Nozzle sleeve area



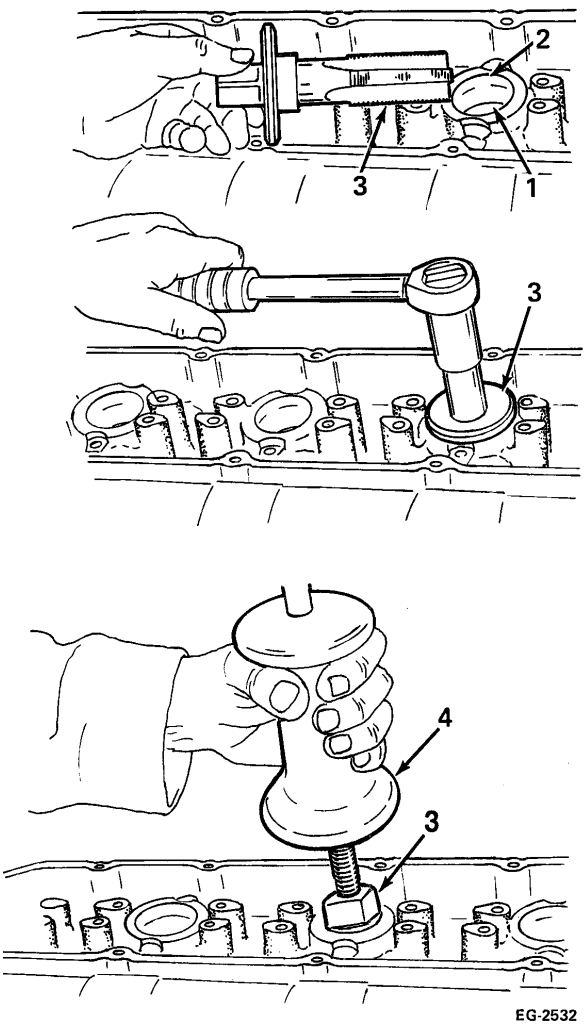
1 - Pressure Plate Mounting Bolts (18)
2 - Spray Bottle

NOTE: *If leakage is observed at any port, upper or lower cylinder head deck, REPLACE CYLINDER HEAD.*

Fuel Injector Sleeve Replacement

NOTE: *If the injector sleeve is going to be removed when In-chassis, place a cork plug into the bore (to prevent debris entering bore or onto piston) before performing procedure.*

Use the following steps to remove fuel injector sleeves.



1 - Fuel Injector Sleeve
2 - Fuel Injector Bore
3 - Injector Sleeve Remover Tool
4 - Slide Hammer

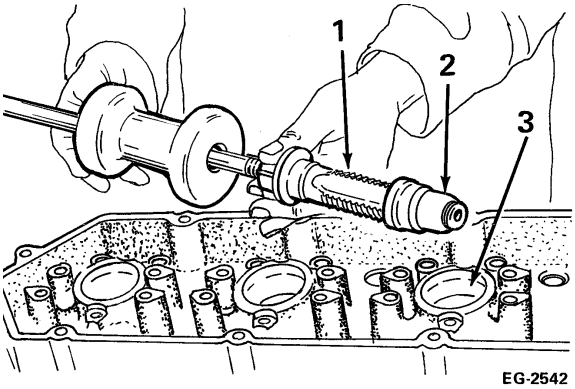
1. Insert injector sleeve remover tool (**ZTSE4302**) into fuel injector sleeve.
2. Turn injector sleeve remover tool to cut threads into fuel injector sleeve.
3. Screw slide hammer (**ZTOEM4263**) into shank of injector sleeve remover tool.

NOTE: *If using a 5/8 inch (16 mm) slide hammer (ZTSE1879) perform the following:*

a. After inserting injector sleeve remover tool (ZTSE4302) into injector sleeve, attach slide hammer adapter (ZT8006) into sleeve remover tool.

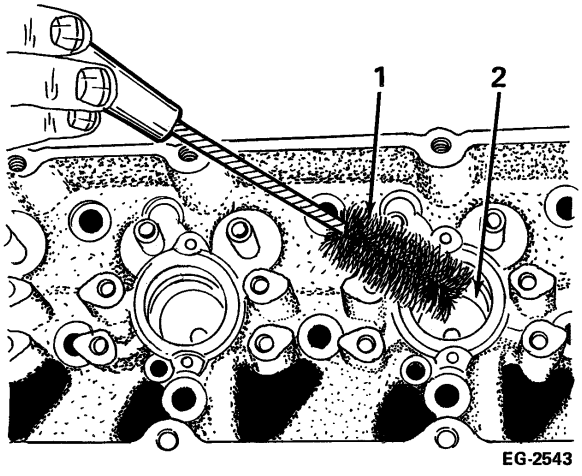
b. Screw slide hammer into shank of slide hammer adapter.

4. Remove fuel injector sleeve.



1 - Adapter
2 - Fuel Injector Sleeve
3 - Fuel Injector Bore

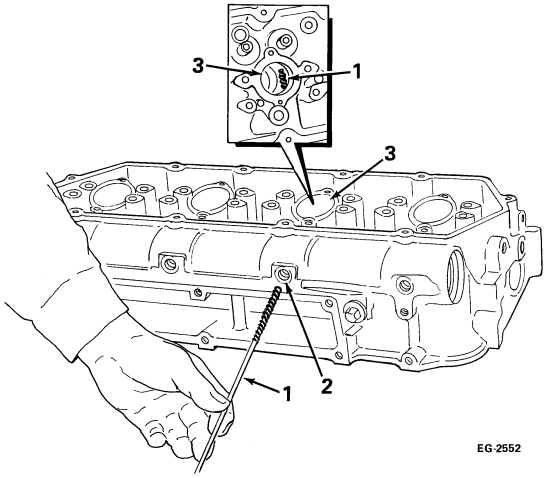
5. Insert a stiff wire brush (**ZTSE4305**) into fuel injector bore and remove deposits and hardened sealant from bore.



1 - Wire Brush
2 - Fuel Injector Bore

6. Remove oil gallery plug, located on top of oil rail of fuel injector bore where sleeve was removed.

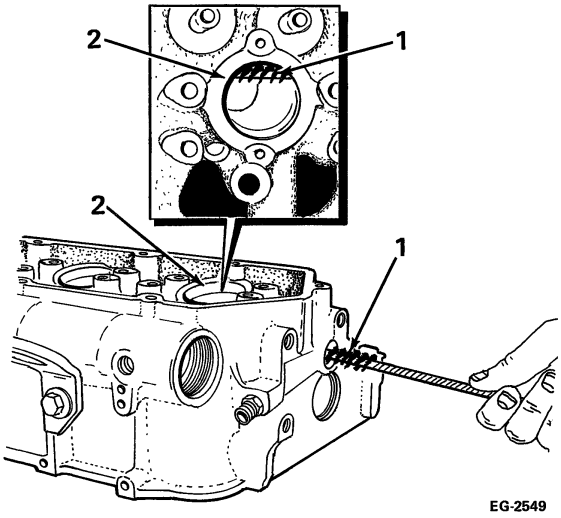
7. Insert a small stiff nylon brush **(ZTSE4320)** into oil gallery for cleaning.



1 - Small Nylon Brush
2 - Oil Galley Port
3 - Fuel Injector Bore

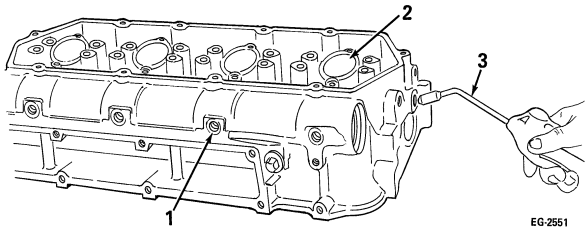
8. Remove two (2) oil gallery plugs and two (2) fuel gallery plugs from the cylinder head. One plug is located on each end of the cylinder head.

9. Clean fuel gallery with a small stiff nylon brush **(ZTSE4320)**.



1 - Nylon Brush
2 - Fuel Gallery

10. Using compressed air to clean out all fuel and oil galleries of all debris.

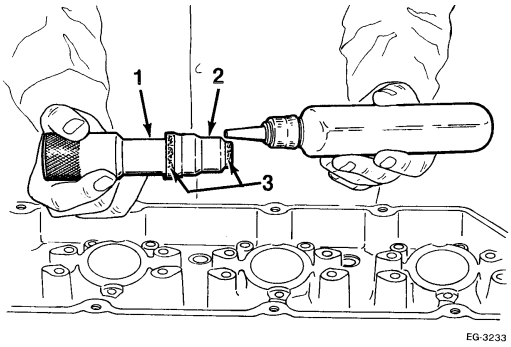


1 - Galley
2 - Fuel Injector Bore
3 - Air Nozzle

11. Attach a new fuel injector sleeve to adapter (**ZTSE4303**) and apply Loctite® 262 to fuel injector sleeve at:

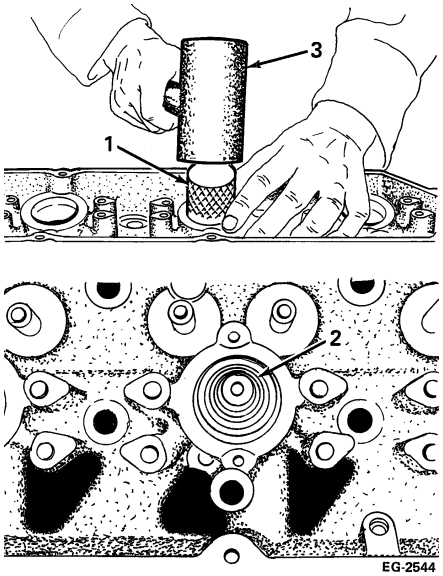
    a. Wall (end)

    b. Upper Wall (top)



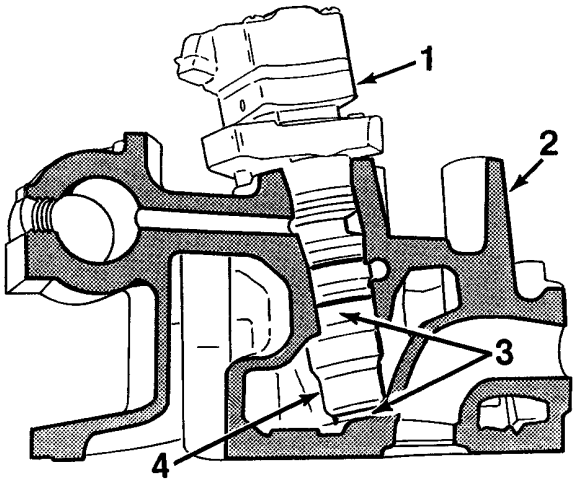
1 - Adapter
2 - Fuel Injector Sleeve
3 - Loctite® Application Area

Use the following steps to install a new fuel injector sleeve.



1 - Adapter
2 - Injector Sleeve
3 - Hammer

12. Insert sleeve into fuel injector bore.
13. Using a hammer, drive sleeve into fuel injector bore.
14. Clean fuel injector sleeve after installation, using **(ZTSE4304)** brush set.
15. Fuel injector and injector sleeve installed into the injector bore. Note areas where injector sleeve lands contact cylinder head.



EG-3255

1 - Fuel Injector
2 - Cylinder Head
3 - Applied Loctite Area
4 - Fuel Injector Sleeve

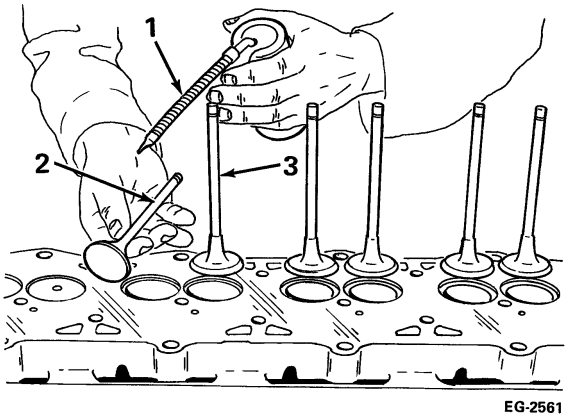
Cylinder Head Reassembly

VALVE REASSEMBLY

1. Clean valve faces and seats with a suitable cleaning solvent to remove all dirt or foreign material. Blow dry all components using filtered compressed air.

IMPORTANT: Guides must be clean! Use a valve guide brush to clean guides.

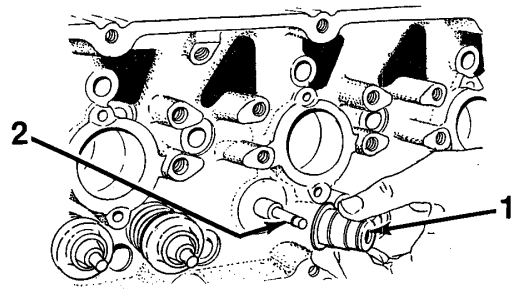
2. Lubricate the valve stems with clean engine oil and insert into valve guide bores.



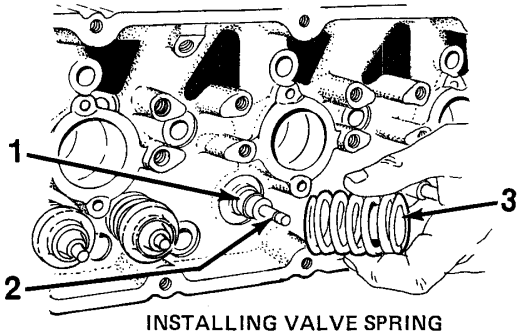
EG-2561

1 - Oil Can
2 - Intake Valve
3 - Exhaust Valve

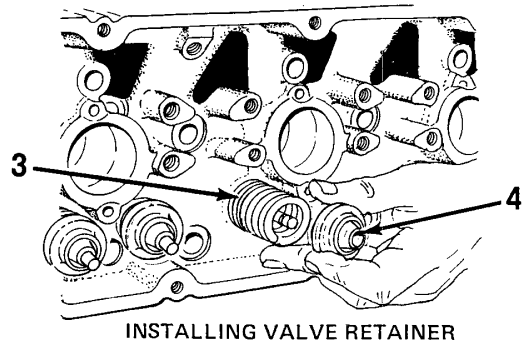
3. Install intake and exhaust valves as follows:
   a. Install valves seals.
   b. Place valve spring and retainer onto valve.
   c. Compress valve spring using valve spring compressor and install retainer keys. Check that retainer keys are correctly seated on all valves.



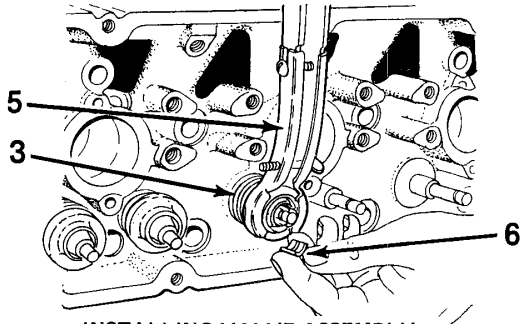
INSTALLING VALVE SEAL



INSTALLING VALVE SPRING



INSTALLING VALVE RETAINER



INSTALLING VALVE ASSEMBLY RETAINER KEYS

EG-3529

1 - Valve Seal
2 - Valve Stem
3 - Valve Spring
4 - Rotator
5 - Valve Spring Compressor Tool
6 - Retainer Keys

4. After valve inspection, reconditioning or replacement and installation, measure valve head recession relative to deck to confirm a good reconditioning job. Refer to **"SPECIFICATIONS"**.

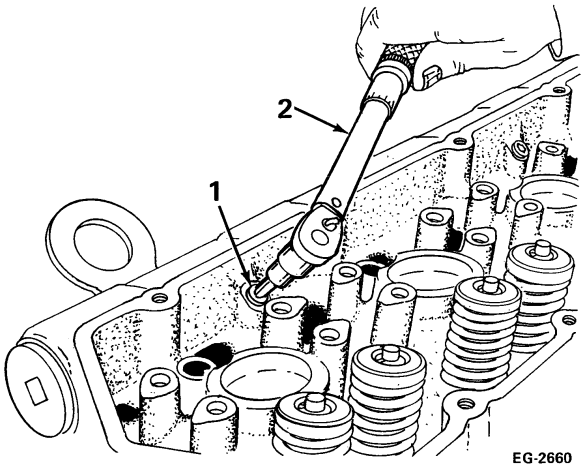
Oil Drain Plugs

NOTE: *Coat end plug and external plugs with Loctite® #277 sealant. Sealant is used to provide redundant seal against fluid leakage.*

1. Install new O-Ring on oil gallery plugs and install into cylinder head. Tighten oil gallery plug to special torque value.

NOTE: *One oil rail plug is located on each end of the cylinder head.*

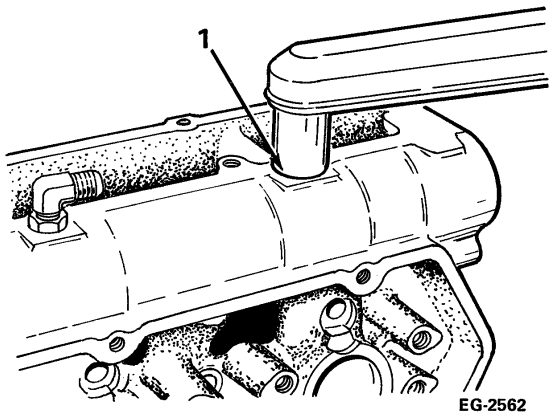
2. Install two (2) oil gallery drain plugs to cylinder head and tighten to special torque value.



EG-2660

1 - Oil Gallery Plug
2 - Wrench

3. Install three (3) oil gallery plugs and one elbow fitting to oil gallery. Tighten to special torque value.



EG-2562

1 - Oil Gallery Access Plugs (3) & Elbow

4. Install intake manifold. Refer to SECTION 7A.

Cylinder Head Gasket Installation

1. Install two (2) dowel sleeves, one at front and one at rear of crankcase. Place cylinder head gasket over dowel sleeves and onto crankcase.

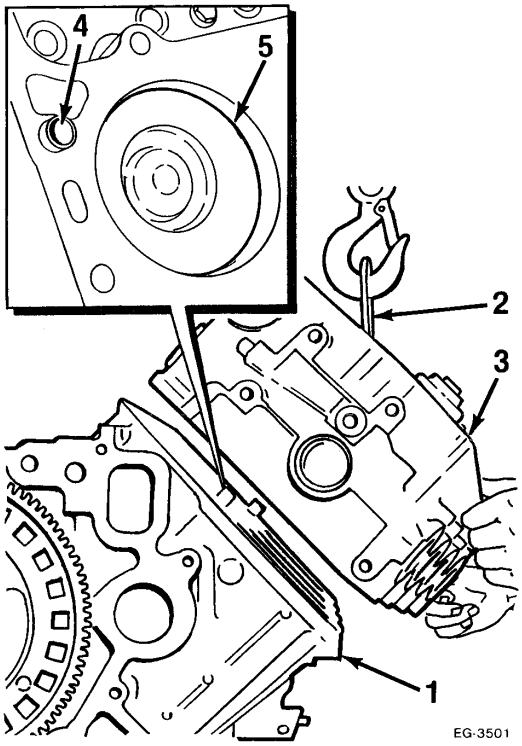
Cylinder Head Installation

NOTE: *Valve lifters can not be replaced or removed when cylinder head is bolted onto the crankcase. Be sure to complete any required work to valve lifters before installing cylinder head.*

IMPORTANT: Do not apply sealer to head gasket surfaces.

NOTE: *When installing cylinder head, BE SURE to align dowel guide pins, located on both sides of the crankcase, with mounting holes in cylinder head.*

1. Install cylinder heads as follows:
   a. Attach lifting sling to cylinder head lifting bracket and lower onto crankcase.



1 - Crankcase
2 - Lifting Bracket
3 - Cylinder Head
4 - Dowel Guide Pins
5 - Piston

⚠CAUTION

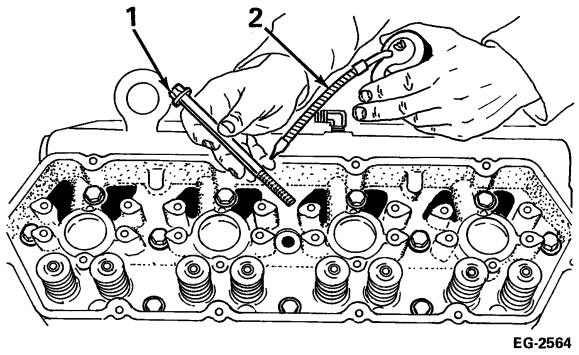
Do not drop cylinder head on gasket or slide it across gasket as either action would damage the cylinder head gasket as well as dowel sleeves resulting in leakage.

   b. Lubricate all cylinder head bolts with clean engine oil on threads and under flange head**.**

IMPORTANT: Lightly lubricate bolt threads and mating surfaces of bolt flanges with engine oil. Too much oil will cause hydrostatic lock and give incorrect torque reading.
Do not use anti-seize compounds, grease or any other lubricant except engine oil. Other lubricants have an adverse effect on torque value.

   c. Tighten cylinder head bolts in sequence to specified torque.

IMPORTANT: Do not install painted cylinder head bolts in a position under the valve cover. Paint chips may contaminate engine lube oil.

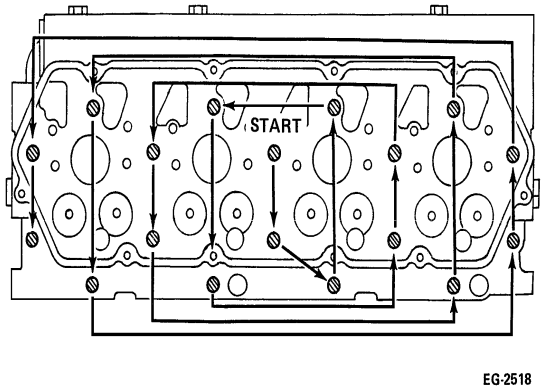


1 - Mounting Bolts (18)
2 - Oil Can

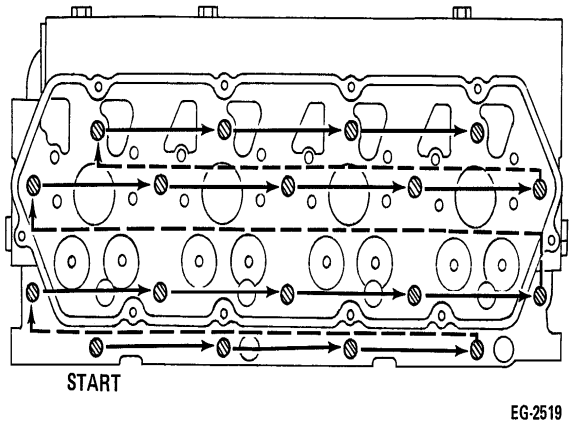
2. Use the following steps to tighten the cylinder head mounting bolts to the proper torque sequence.

   Step 1. 65 lb.ft. (88 N·m)

   Step 2. 85 lb.ft. (115 N·m)

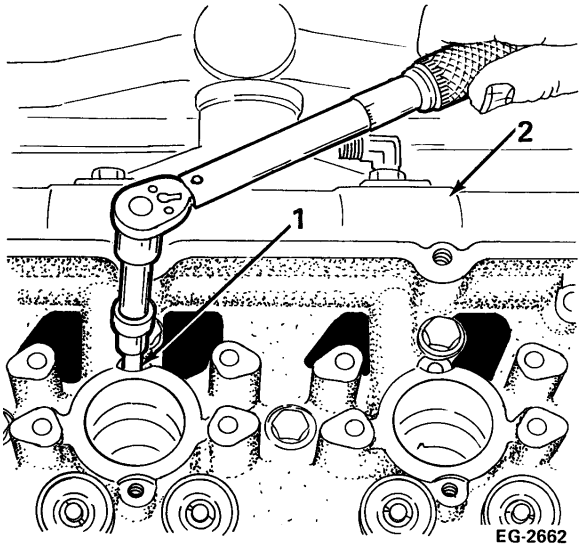


Step 3. 105 lb.ft. (142 N·m).



FUEL INJECTOR REASSEMBLY

1. Install shoulder bolt and tighten to specified torque value.

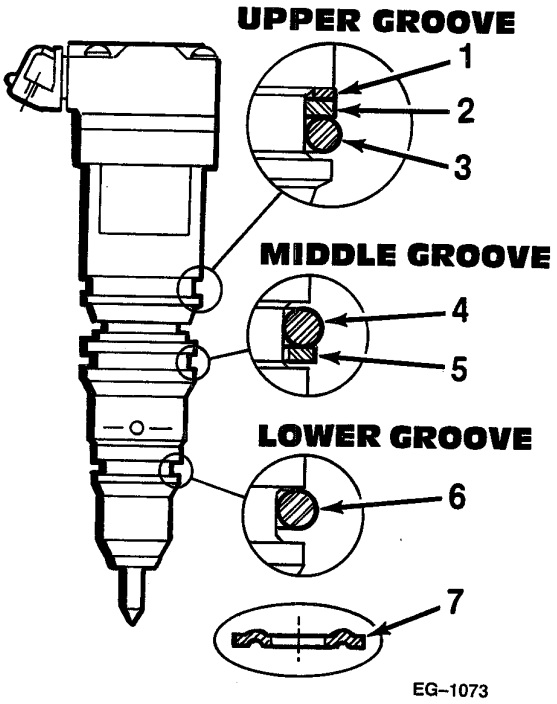


1 - Shoulder Bolt
2 - Cylinder Head

2. Install new fuel injector O-Rings as shown in.

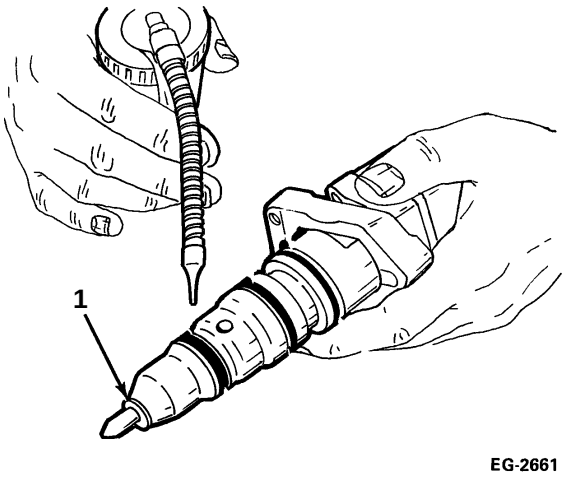
NOTE: *Injector O-rings must be lubricated with clean engine oil.*

IMPORTANT: When installing o-rings onto the injectors, be sure all o-rings and seals are located to the top of the o-ring grooves. This action will prevent the o-rings and seals from trying to roll in their respective grooves during the installation procedure.



1 - Back-Up Ring
2 - Cushion Ring
3 - Upper Injector Seal
4 - Middle Injector Seal
5 - Cushion Ring
6 - Lower Injector Seal
7 - Injector gasket

3. Install a new copper gasket at the injector tip. Push to seat with a deep well socket.

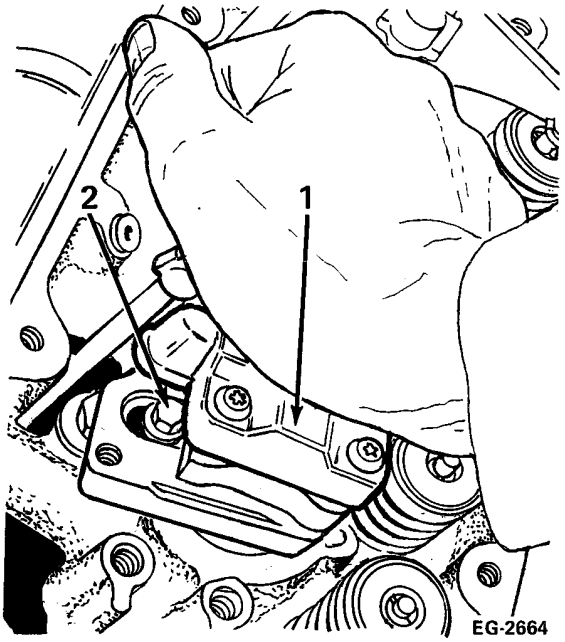


1 - Copper Gasket

NOTE: *The bump on the copper gasket goes toward the fuel injector.*

4. Lubricate fuel injector and insert injector assembly in bore of cylinder head.

NOTE: *Do not strike top of injector to seat it! Use hand pressure on top of injector until hold down clamp can be engaged under the head of the shoulder bolt.*



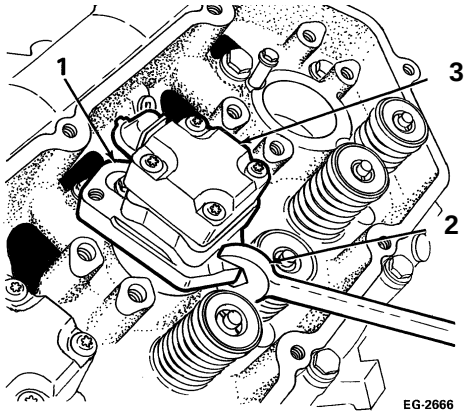
1 - Fuel Injector
2 - Shoulder Bolt

5. There are two methods to seat the fuel injector into the fuel injector bore. Use one of the following two methods.

Method One:

With hold down clamp over shoulder bolt use a 5/8 inch (16mm) open end wrench on lower edge of hold down clamp to further install injector in bore of cylinder head until seated.

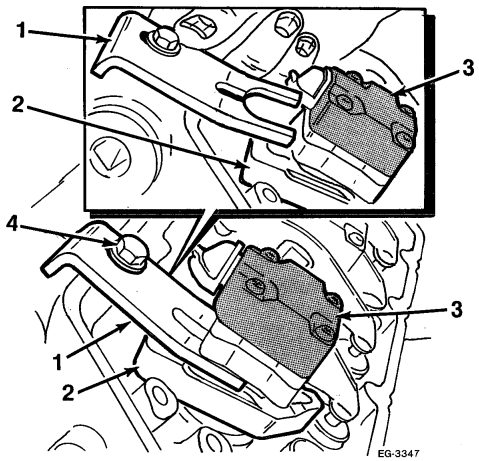
EG-1073



1 - Hold Down Clamp
2 - Fuel Injector
3 - Wrench

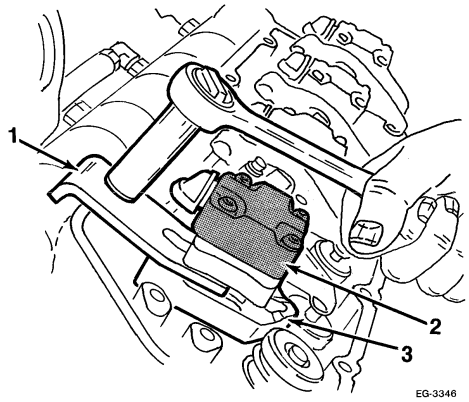
Method Two:

1. Place injector installer tool **ZTSE4353** onto fuel injector. Slide installer tool forks in between hold down clamp and fuel injector head and rest the lip of the tool on the cylinder head.



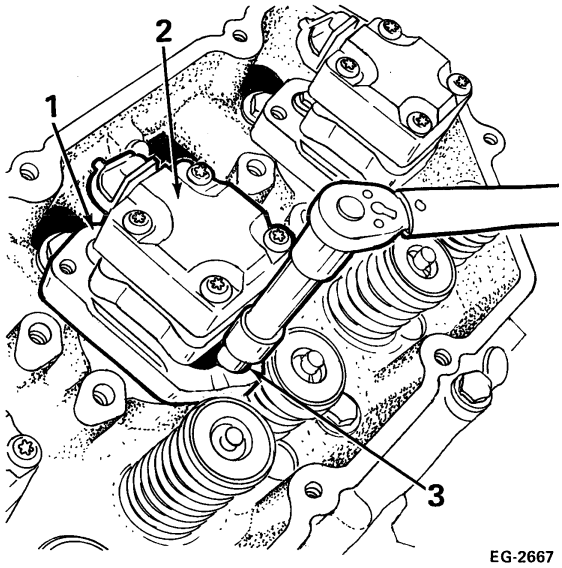
1 - Installer Tool
2 - Hold Down Clamp
3 - Fuel Injector
4 - Bolt

2. Turn bolt of installer tool to seat fuel injector into bore.



1 - Installer Tool
2 - Fuel Injector
3 - Hold Down Clamp

3. Install fuel injector hold down clamp mounting bolt and tighten to specified torque value.

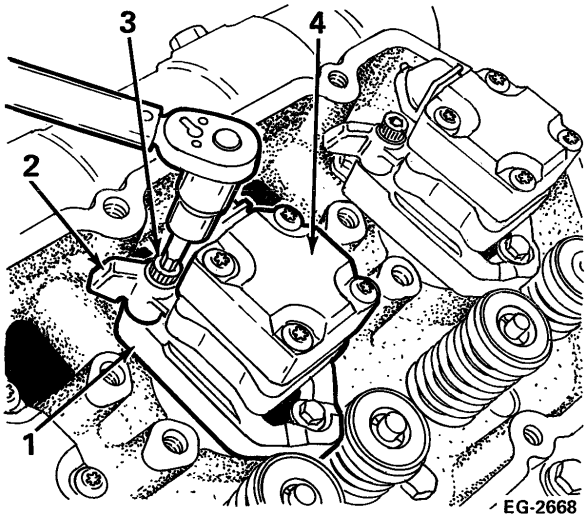


1 - Hold Down Clamp
2 - Fuel Injector
3 - Hold Down Clamp Mounting Bolt

⚠CAUTION

IT IS IMPERATIVE THAT INJECTOR HOLD DOWN CLAMP BOLT BE TIGHTENED TO THE SPECIAL TORQUE VALUE.

4. Install oil spill spout and secure with allen head bolt. Tighten to specified torque value.

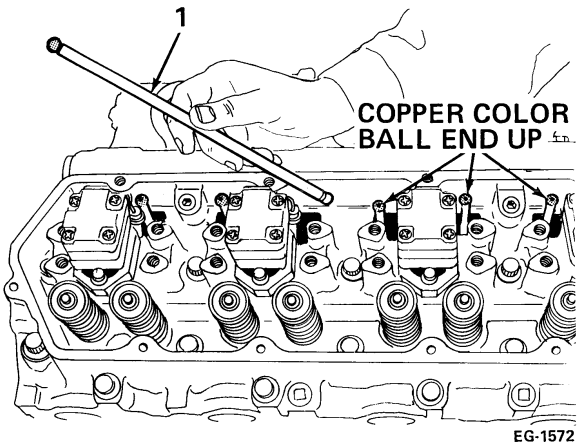


1 - Hold Down Clamp
2 - Oil Spill Spout
3 - Oil Spill Spout Mounting Bolt
4 - Fuel Injector

INSTALLING PUSH RODS

NOTE: *Refer to Section 6 for the cleaning and inspection of the push rods prior to installation.*

1. Insert push rods into their respective positions with copper colored end up.



1 - Push Rod

IMPORTANT: Be sure the copper end of the push rod is up. Failure to follow this procedure will result in push rod failure.

NOTE: *Higher mileage engines require push rods to be cleaned so the copper color end of the push rod can be identified.*

INSTALLING VALVE LEVER ASSEMBLY

1. Install valve lever assemblies as follows:

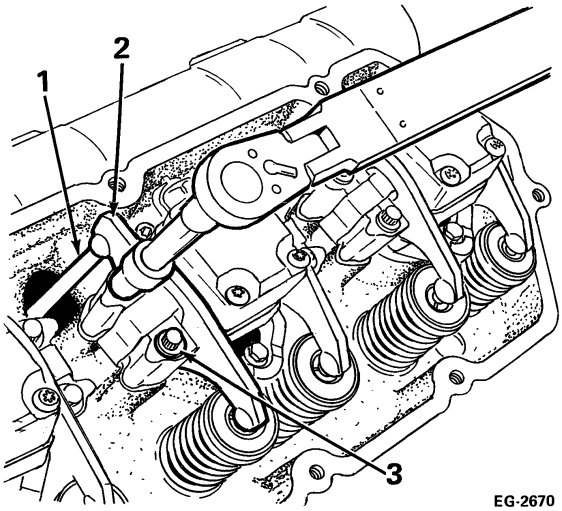
IMPORTANT: Be sure the copper ends of the push rods are up and they are inserted in the hydraulic roller follower sockets before installing valve lever assemblies.

NOTE: *Rotate the crankshaft until damper notch is 15° from vertical. This positions all pistons below TDC, so the valves do not contact the pistons when tightening the valve lever assemblies.*

   a. Lubricate valve lever assemblies and bolts with clean engine oil.

   b. Place intake and exhaust valve lever assemblies in their original location over cylinder head mounting pads and install retaining bolts finger tight.

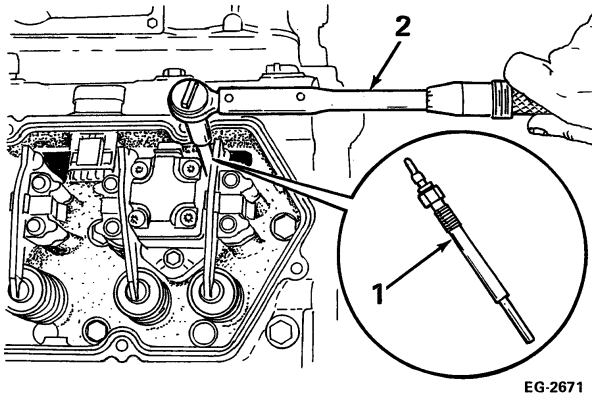
   c. Tighten valve lever mounting bolts to specified torque value.



1 - Push Rod Assembly
2 - Valve Lever
3 - Valve Lever Mounting Bolt

INSTALLING GLOW PLUG

1. Install glow plugs into cylinder head. Tighten glow plugs to specified torque value.

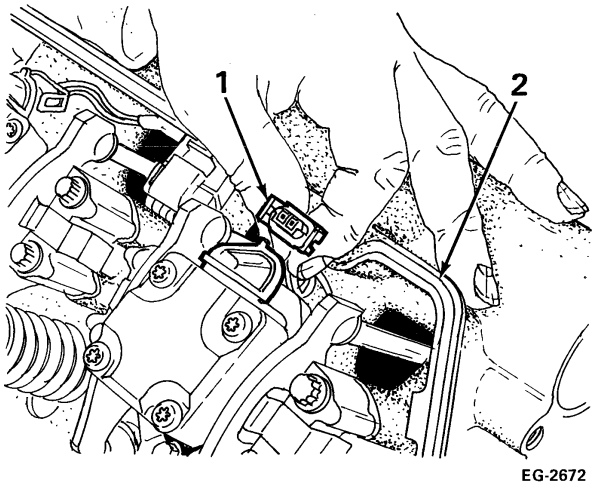


1 - Glow Plug
2 - Torque Wrench

2. Connect and push down on glow plug leads.

CONNECTING UNDER VALVE COVER (UVC) HARNESS

1. Position valve cover gasket with UVC harness on cylinder head.
2. Connect UVC harness as follows:
   a. Place UVC harness assembly on cylinder between injectors.
   b. Push on injector leads. Be sure rubber sealing grommets are in place prior to connecting lead to injector solenoid.
   c. Connect glow plug leads.



1 - Glow Plug Lead
2 - Under Valve Cover

NOTE: *Make sure all UVC wiring is free and clear of any moving part.*

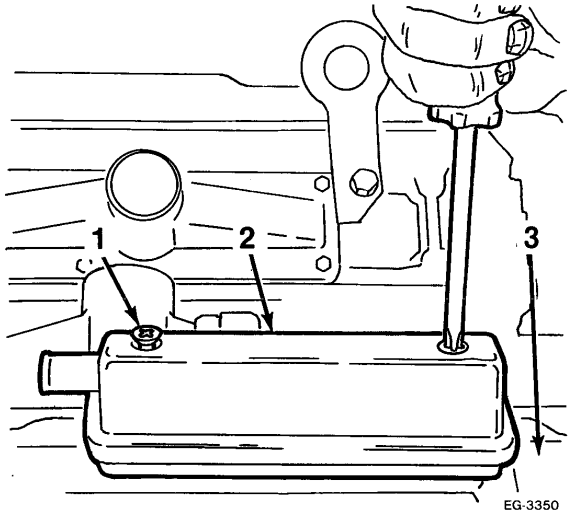
VALVE COVERS

1. Install valve covers as follows:
   a. Install valve cover on gasket with care to avoid pinching any UVC wires.
   b. Tighten all bolts finger tight.
   c. Tighten all valve cover bolts to the specified torque value.

Crankcase Breather

DISASSEMBLY

1. Remove crankcase breather assembly as follows:
   a. Remove two screws securing crankcase breather assembly to left valve cover. Remove breather assembly from valve cover.



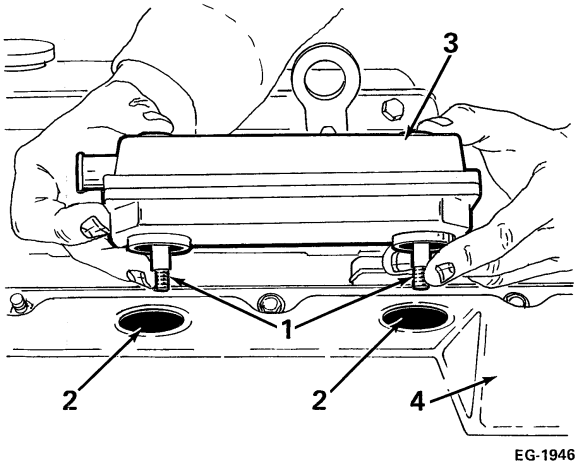
1 - Mounting Screws
2 - Crankcase Breather Assembly
3 - Left Valve Cover

CLEANING BREATHER ELEMENT

Clean breather element in solvent and dry with compressed air.

REASSEMBLY

1. Align crankcase breather assembly with two mounting holes on left valve cover and secure with two mounting screws.



1 - Mounting Screws
2 - Inner O-Ring Seals
3 - Crankcase Breather
4 - LH Valve Cover

NOTE: *Be sure inner O-Ring seals are in place as they seal the crankcase breather assembly to the LH valve cover.*

Specifications - Vibration Damper, Lube Oil Pump, Oil Pan, Pick-up Tube and Front Cover

Lubricating Oil Pump

Type	Gerotor
Drive	Crankshaft
End Clearance-Inner and Outer Rotor to Housing	0.001-0.003 in. (0.02-0.08 mm)
Radial Clearance Between Outer Rotor Housing	0.028-0.032 in. (0.71-0.81 mm)
Engine Lube Oil Pressure:	
(Engine at Operating Temperature)	
At Low Idle Speed (700 rpm) (Minimum)	10 psi (69 kPa)
At High Idle Speed	40-70 psi (276-482 kPa)

Engine Oil Capacity

Total Capacity (Including filter and cooler)	16.5 qts. (15.6 L)

Damper

Runout	
Damper Mounting Area Runout (Max.)	0.001 in. (0.03 mm)

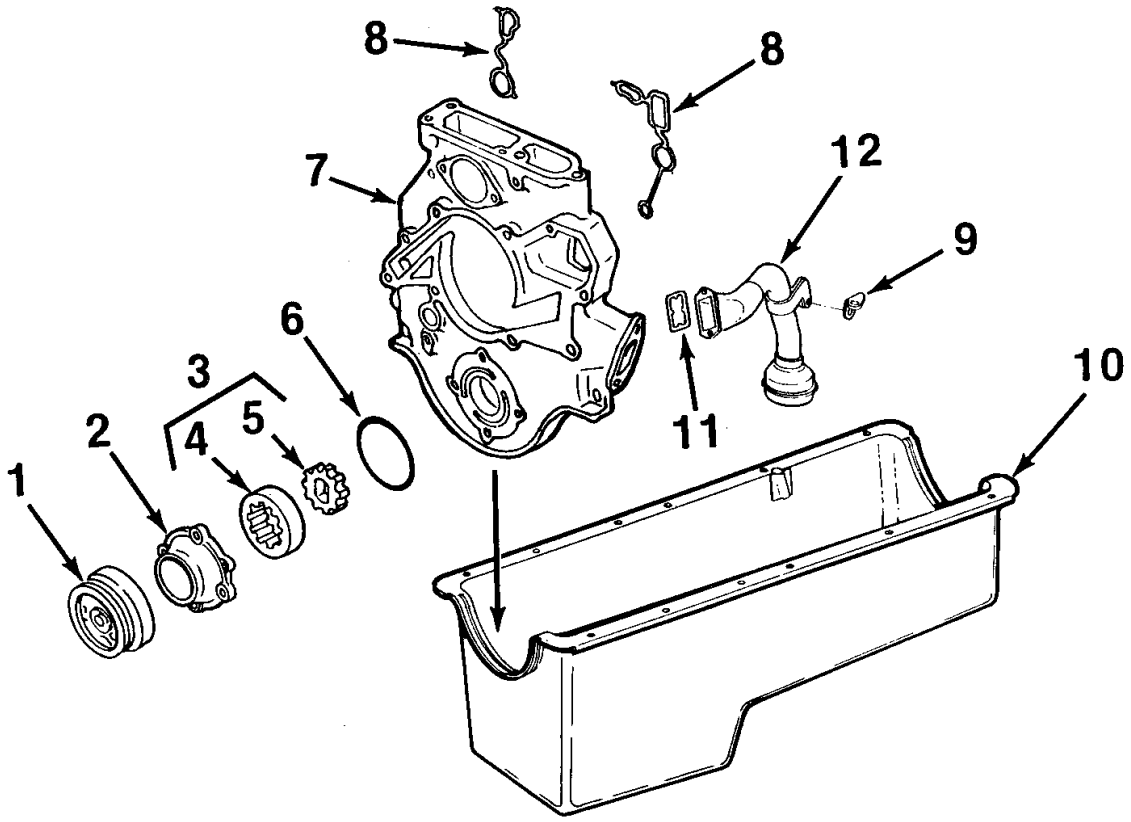
Special Torque Values

Oil Pan Drain Plug	28 lb.ft. (37 N·m)
Crankshaft Vibration Damper Bolt	212 lb.ft. (287 N·m)
Oil Pick-Up Tube Flange Bolts	18 lb.ft. (24 N·m)
Oil Level Gauge Tube Adapter Nut	24 lb.ft. (33 N·m)
Front Cover Mounting Bolts	15 lb.ft. (20 N·m)

Special Service Tools

Tools	Description
ZTSE-4385	Oil Pan RTV Gasket Cutter
ZTSE-4314	Damper Wear Ring Remover
ZTSE-4315	Damper Wear Ring Installer
ZTSE-4310	Damper and Front Seal Installer

Oil Pump and Pickup Assembly



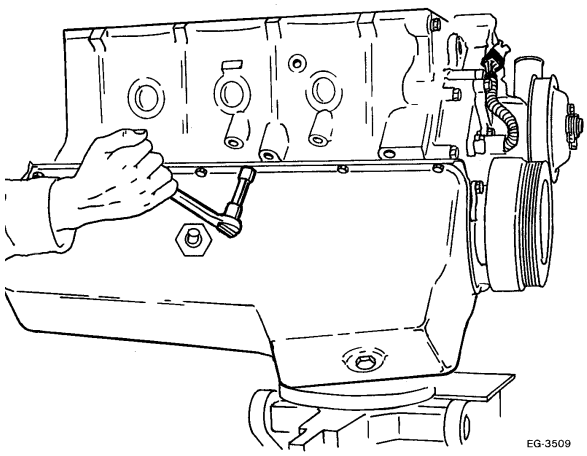
EG-3234

1 - Vibration Damper
2 - Oil Pump Housing (2)
3 - Oil Pump Gerotor Assembly Bracket
4 - Large Oil Pump Rotor
5 - Small Oil Pump Rotor
6 - Oil Pump Housing Gasket
7 - Front Cover
8 - Front Cover Gasket
9 - Oil Pick-up Tube
10- Oil Pan
11- Oil Pick-up Tube Gasket
12- Oil Pick-up Tube

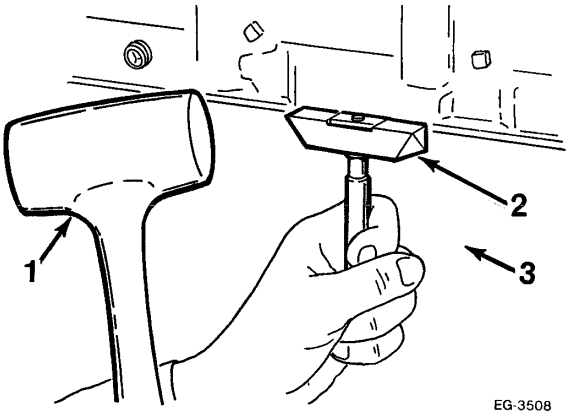
Oil Pan

Removal

1. Remove oil pan as follows:
   a. Remove oil pan mounting bolts [six per side].

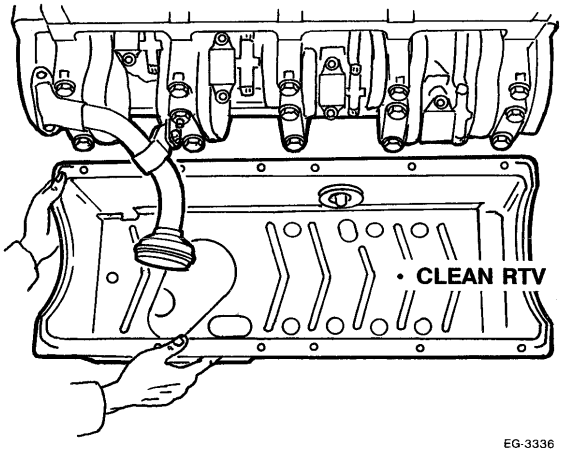


   b. Cut through RTV seal on both pan rails using tool **ZTSE-4385**.



1 - RTV Cutting Tool
2 - Hammer
3 - Oil Pan

   c. Pry up one side of oil pan to break seal at front cover and rear plate. Roll pan off to side to free it from engine.

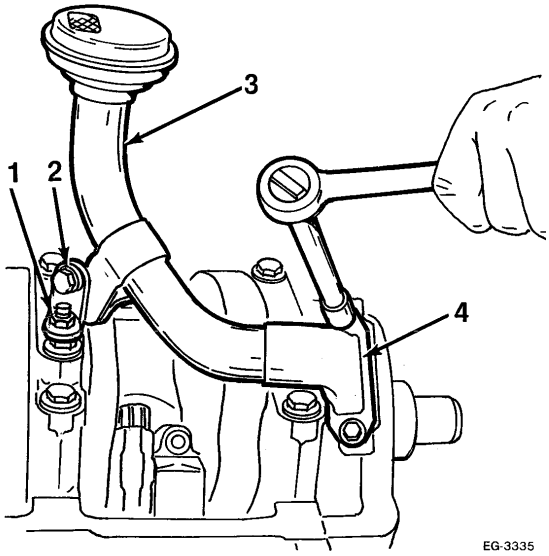


   d. Clean RTV sealant from oil pan and crankcase mating surface.

Oil Pickup Tube

Removal

1. Remove oil pickup tube as follows:
   a. Remove fasteners from oil pick up tube flange and support bracket. Remove tube assembly from engine.
   b. Visually inspect pickup tube assembly for cracks at the seams and brazed connections. Replace as required.

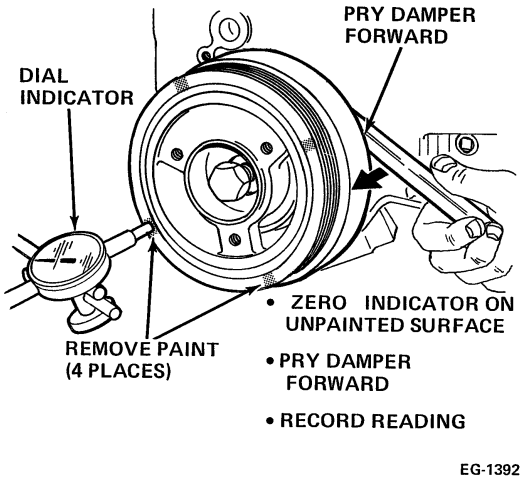


1 - Bolt
2 - Bracket
3 - Oil Pick-up Tube
4 - Flange

Vibration Damper

Removal

1. Prior to vibration damper removal, inspect the vibration damper for run out as follows:



   a. Remove paint from face of damper at 4 points 90° apart.

   b. Attach a magnetic base dial indicator to front of crankcase. Position indicator point on unpainted surface.

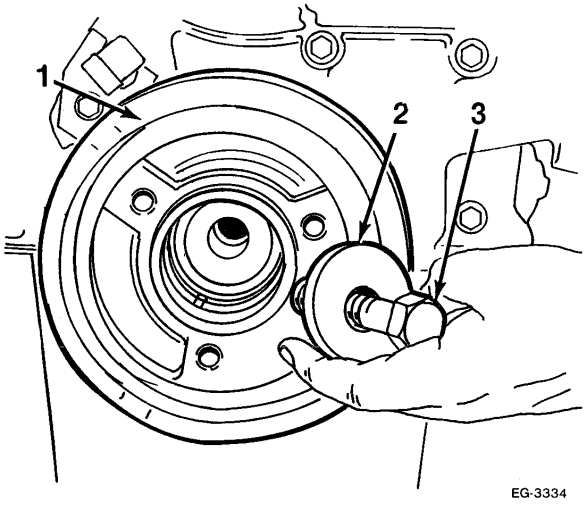
   c. Pry crankshaft forward and “zero” indicator. This becomes the baseline.

   d. Turn the crankshaft 90°, pry the crankshaft forward and record reading.

   e. Repeat at each unpainted surface. If run out exceeds specification, replace damper.

IMPORTANT: Pry only in one direction, to eliminate possible error induced by crankshaft end play.

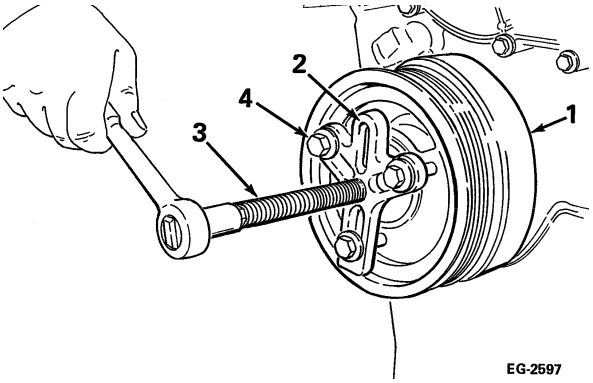
2. Remove crankshaft vibration damper bolt.



1 - Vibration Damper
2 - Washer
3 - Mounting Bolt

NOTE: *Remove washer and loosely install bolt in place so puller does NOT damage Damper Bolt Threads.*

3. Remove vibration damper using an appropriate puller.



1 - Vibration Damper
2 - Puller
3 - Forcing Screw
4 - Remover Mounting Bolts

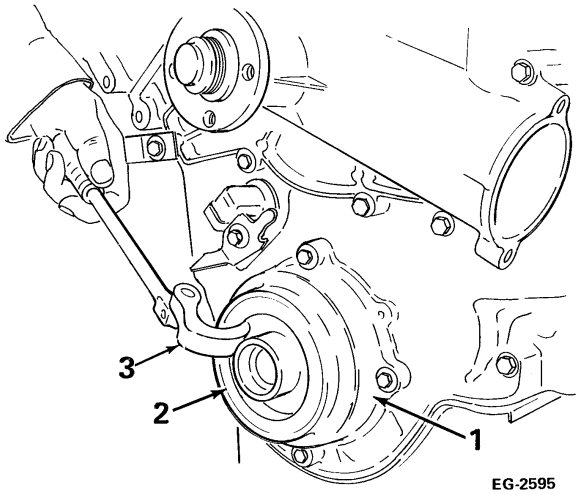
IMPORTANT: Pull against damper mounting bolt to prevent thread damage.

   a. Attach puller as shown.

   b. Turn forcing screw to remove damper.

Front Oil Seal

1. Remove front oil seal as follows:
   a. Using injector and oil seal removal tool (**ZTSE4300**), pry front oil seal from oil pump housing.

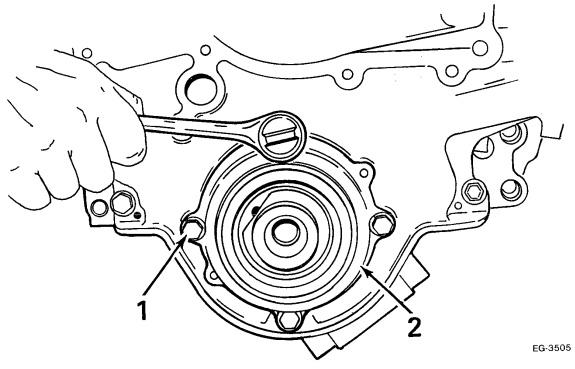


1 - Oil Pump Housing
2 - Oil Sea
3 - Oil Seal Removal lTool #ZTSE4300

Oil Pump

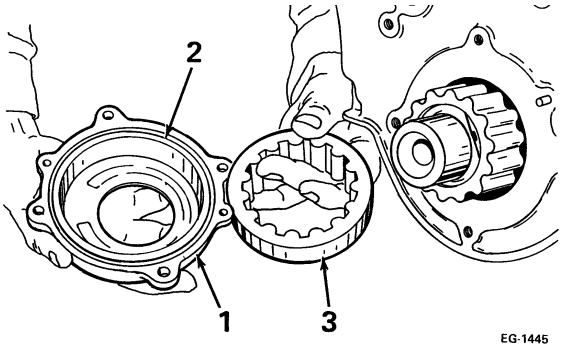
Removal

1. Remove oil pump as follows:
   a. Remove four (4) oil pump housing retaining bolts and washers.



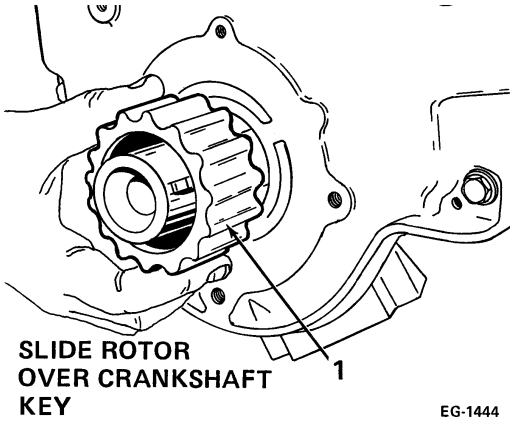
1 - Retainer Bolt (4)
2 - Oil Pump Housing

   b. Remove oil pump housing with square cut seal ring and the outer rotor. Discard seal ring.



1 - Oil Pump Housing
2 - Seal Ring (Square Cut)
3 - Outer Rotor

   c. Remove inner rotor by sliding it off crankshaft.

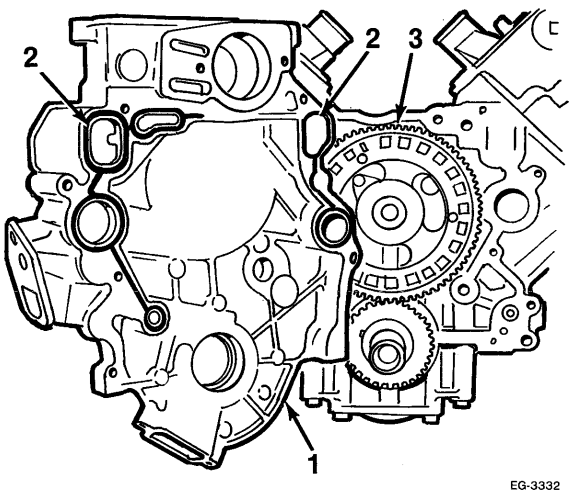


1 - Inner Rotor

Removal

FRONT COVER

1. Remove four front cover mounting bolts.



1 - Front Cover
2 - Front Cover Gasket
3 - Gear Train

2. Remove front cover from crankcase to expose gear train.
3. Remove and discard front cover gaskets.
4. Clean RTV sealant from front cover and crankcase mating surface.

Vibration Damper

Cleaning

1. Clean damper using a suitable solvent.

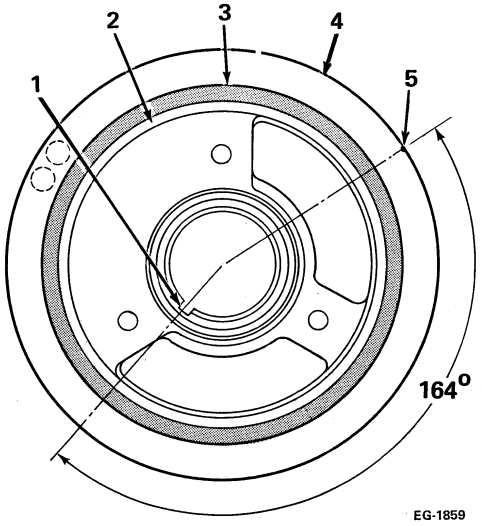
⚠CAUTION

DO NOT IMMERSE DAMPER IN PETROLEUM BASED SOLVENT. DAMAGE TO RUBBER DAMPING ELEMENT MAY RESULT.

2. Dry with filtered compressed air.

Inspection and Repair

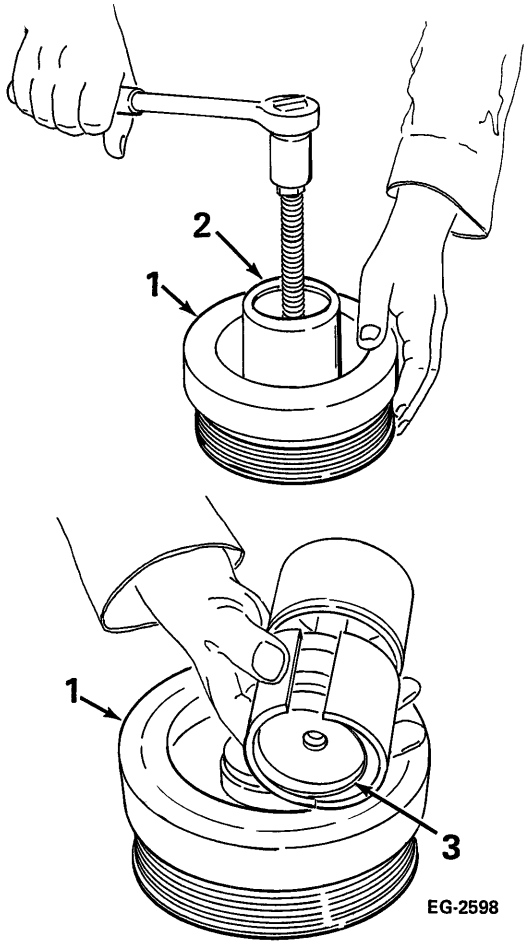
1. Inspect vibration damper members for alignment. Using a protractor, measure the angle between the timing mark and the center of key way. If angle is other than 164° , replace damper. Refer to **Figure 5.14**.



1 - Keyway
2 - Inner Member
3 - Rubber Member
4 - Outer Member
5 - Timing Mark

WEAR SLEEVE REMOVAL

1. Whenever the vibration damper is removed, replace crankshaft front oil seal wear sleeve as follows:
   a. Install wear sleeve removal tool **ZTSE4314** onto vibration damper.
   b. Turn forcing screw to remove wear sleeve.

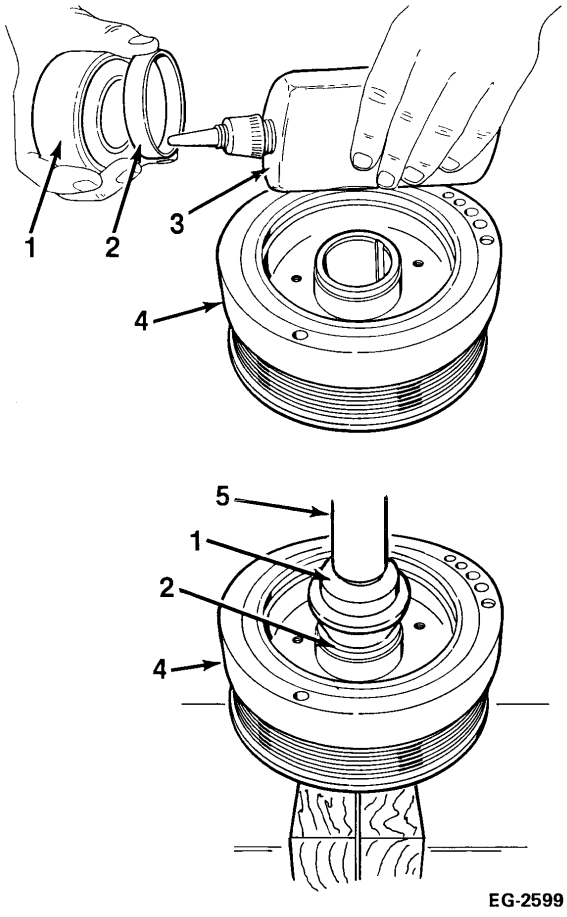


1 - Vibration Damper
2 - Wear Sleeve Removal Tool
3 - Wear Sleeve

WEAR SLEEVE INSTALLATION

1. Install new wear sleeve as follows:
   a. Apply Loctite® 262 to wear sleeve. Place wear sleeve onto installer tool ZTSE - 4315.
   b. Position wear sleeve into installer tool so the outer chamfer is towards tool.
   c. Place installer on a press table.
   d. Position and lower damper onto tool and wear sleeve.

e. Using a press, apply pressure to the inner member of the vibration damper until the installation tool bottoms out or seats.



1 - Wear Sleeve Installer Tool
2 - Wear Sleeve
3 - Loctite® 262
4 - Vibration Damper
5 - Press

Oil Pump

Cleaning

1. Wash all parts thoroughly in a suitable solvent.
2. Dry with filtered compressed air.

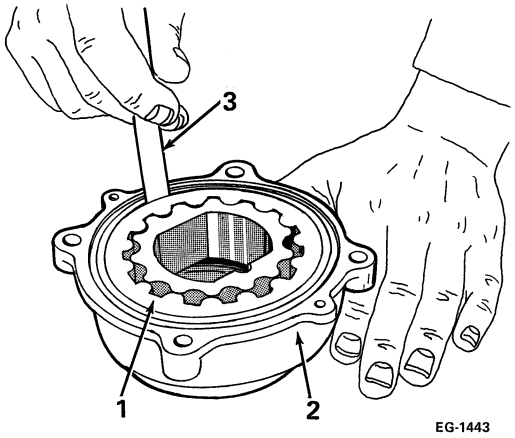
Inspection

1. Visually inspect rotors and housing for nicks, burrs or scoring.
2. Replace any damaged components.

NOTE: *The inner and outer rotors are a matched set and cannot be replaced separately.*

INSPECT FOR WEAR AS FOLLOWS:

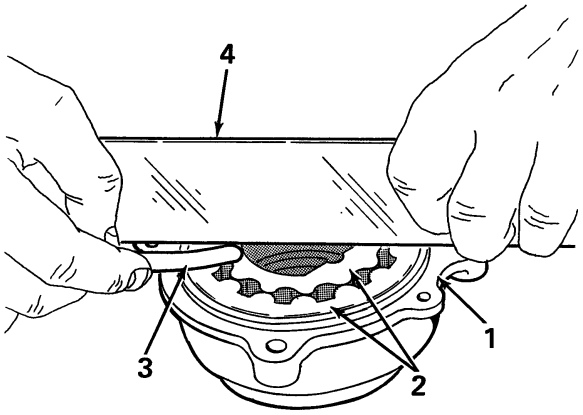
3. Check radial clearance between outer rotor and pump housing using a feeler gauge. Compare to **"SPECIFICATIONS."**



1 - Outer Rotor
2 - Oil Pump Housing
3 - Feeler Gauge

NOTE: *The crankshaft woodruff key can remain in place when removing the inner rotor.*

4. Check oil pump end clearance as follows:
   a. With O-Ring removed from oil pump housing, place a straightedge across the housing.
   b. Insert feeler gauge under straightedge at inner and outer rotors and compare end clearance with **"SPECIFICATIONS**").
   c. If either measurements are not within specifications, replace pump assembly.



EG-1442

1 - Oil Pump Housing
2 - Rotors
3 - Feeler Gauge
4 - Straightedge

Front Cover

Cleaning

Clean all old RTV and gasket material from the mating surfaces using a drill and Scotch-Brite® disc.

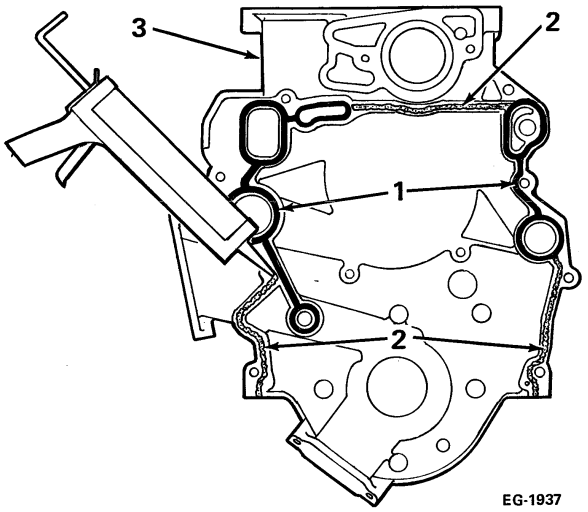
Inspection

1. Visually inspect the front cover for cracks.
2. Place mounting surface of front cover on a smooth flat surface and check for warpage.
3. Replace front cover if cracked or warped.

FRONT COVER AND WATER PUMP INSTALLATION

IMPORTANT: Water pump must be installed prior to tightening front cover bolts. Four of the water pump bolts also secure front cover.

1. Position two new gaskets and apply Wacker T-95 in remaining sealing grooves on front cover.

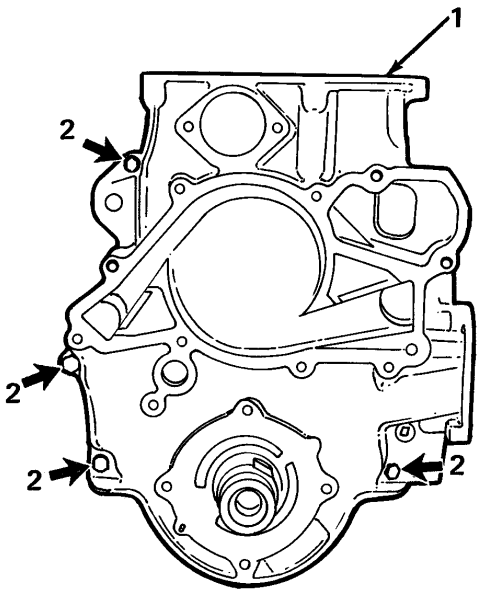


EG-1937

1 - New Gaskets
2 - Wacker T-95 Locations
3 - Front Cover

NOTE: *Apply Wacker T-95 around front cover dowel pins.*

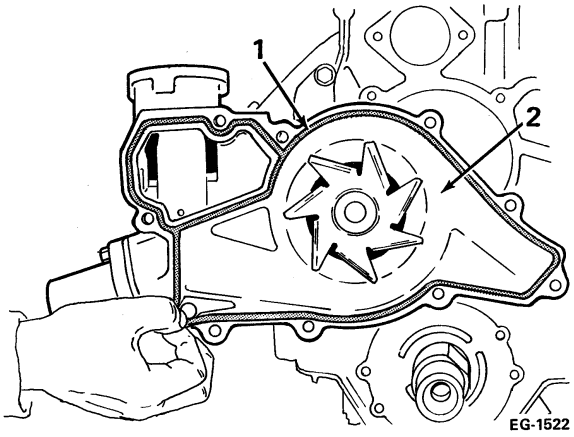
2. Fasten front cover to crankcase, using mounting bolts tighten finger tight.



EG-1419

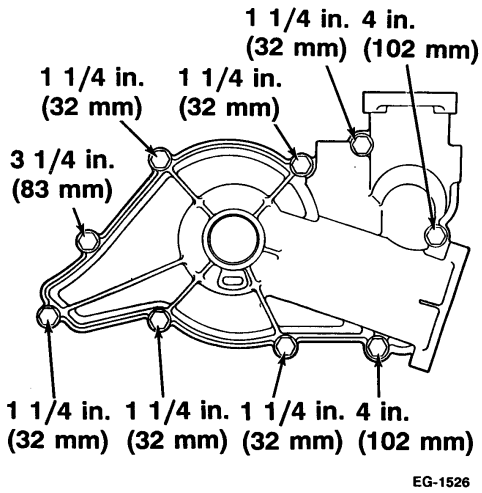
1 - Front Cover
2 - Front Cover Mounting Bolts

3. Place a new gasket in water pump gasket groove.

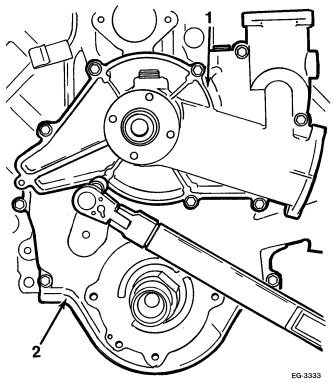


1 - Water Pump Gasket
2 - Water Pump

4. Install and secure water pump to front cover using nine (9) mounting bolts.



5. Tighten front cover and water pump bolts to specified torque.

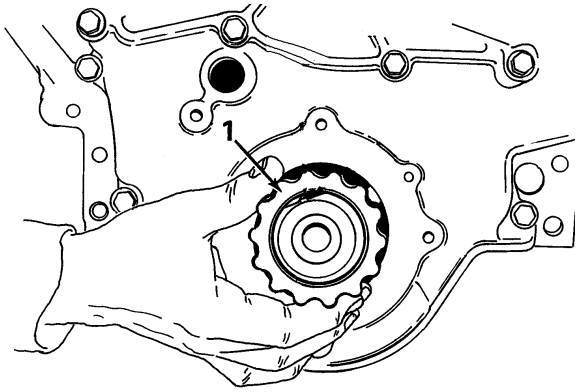


1 - Water Pump
2 - Front Cover

Oil Pump

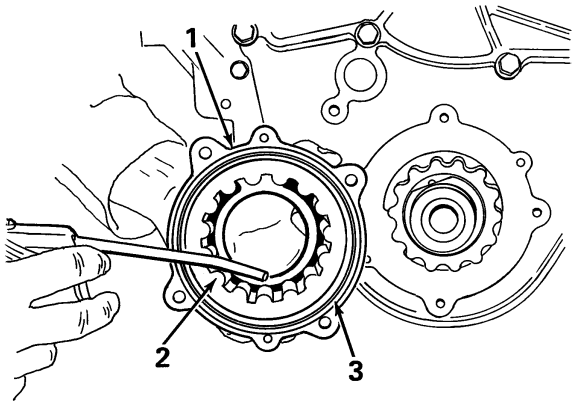
Reassembly

1. Install inner gerotor gear over crankshaft nose.



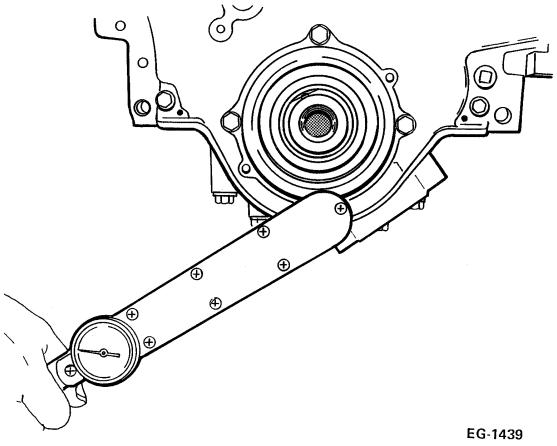
1 - Inner Rotor

2. Lubricate outer gerotor gear with engine oil and install into oil pump housing. Install oil pump housing square cut seal ring.



1 - Oil Pump Housing
2 - Outer Gerotor (Square Cross Section)
3 - Sealing Ring

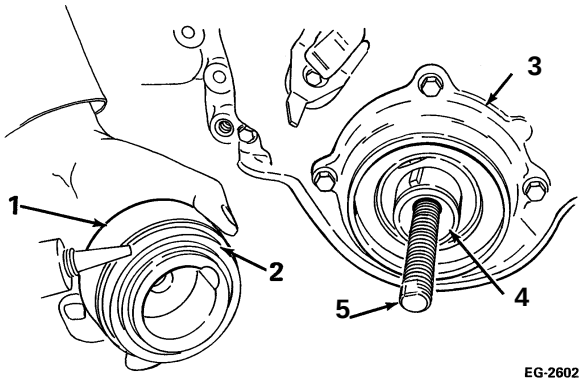
3. Align dowel pins and install oil pump housing with seal ring and large gerotor gear onto crankshaft. Install four (4) retaining bolts and washers and tighten to specified torque.


EG-1439

Front Cover

FRONT OIL SEAL INSTALLATION

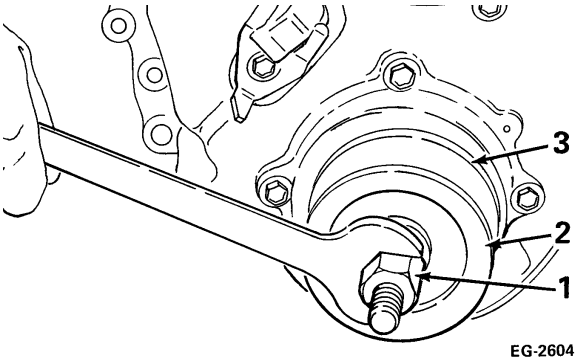
1. Place front oil seal onto installation tool ZTSE-4310.



EG-2602

1 - Installation Tool
2 - Oil Seal
3 - Oil Pump
4 - Crankshaft
5 - Forcing Screw

2. Apply a thin coat of Aviation Permatex No. 3 to the oil seal outside diameter.
3. After positioning installer over forcing screw, tighten forcing nut driving oil seal into position in housing until tool bottoms against housing.



EG-2604

1 - Forcing Nut
2 - Installation Tool
3 - Oil Seal

VIBRATION DAMPER INSTALLATION

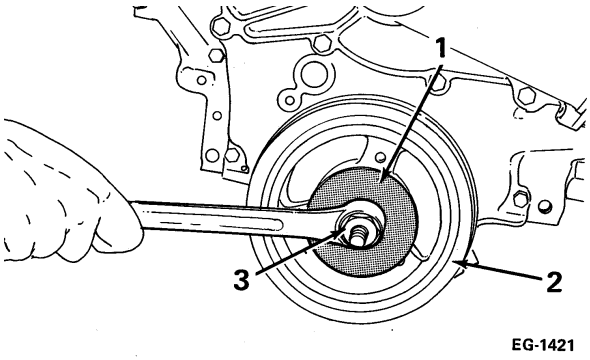
NOTE: *Prior To Installing Damper, Prime Oil Pump With Generous Supply Of Clean Engine Oil. Inspect Damper Hub To Insure Oil Seal Wear Ring Is In Place.*

1. Install crankshaft vibration damper using ZTSE-4310, damper/front seal installer.

NOTE: *ZTSE-4310 is a combination tool. One side is used to install the seal and the other side is used to install the damper.*

a. Align keyway in damper with key on crankshaft.

b. Assemble puller screw, installer plate, thrust washer, and nut.



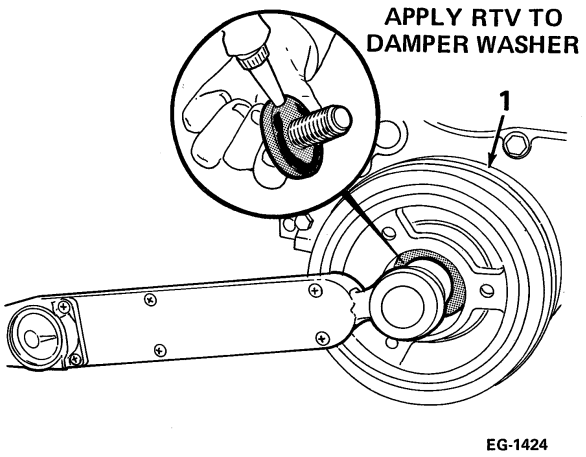
EG-1421

1 - Installer Plate
2 - Vibration Damper
3 - Forcing Nut

c. Turn nut to draw the damper onto the crankshaft.

d. Remove tool and install damper bolt and washer. Tighten to specified torque.

NOTE: *Apply RTV to washer. This prevents oil seepage through damper keyway.*

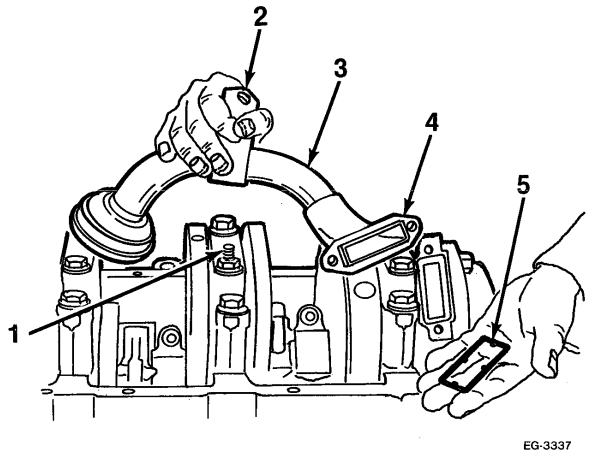


1 - Vibration Damper

Oil Pan

OIL PICK UP TUBE AND OIL PAN INSTALLATION

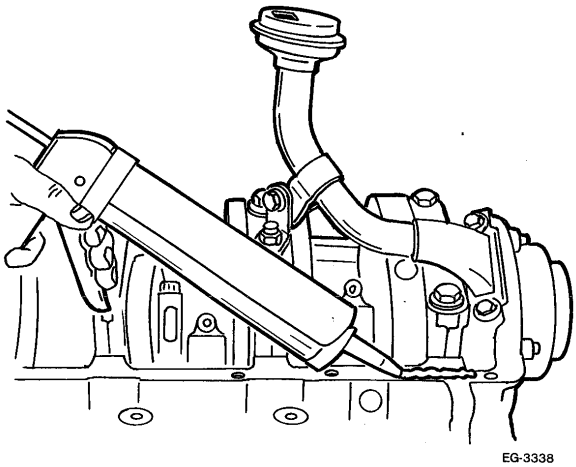
1. Install O-Ring on oil pick-up tube mounting flange. Use small amount of RTV to hold in place, if necessary.
2. Install pick-up tube at the front cover and main bearing stud bolt. Tighten flange bolts finger tight, then adjust and tighten bracket nut at the main bearing cap stud. Tighten flange bolts to specified torque after alignment.



1 - Stud-Bolt
2 - Bracket
3 - Oil Pick-up Tube
4 - O-Ring
5 - Flange

NOTE: *Wipe off all excess oil and foreign matter from sealing surface on crankcase, front plate, rear cover and oil pan. Use brake cleaner to thoroughly degrease all sealing surfaces prior to application of Wacker T-95 Sealant.*

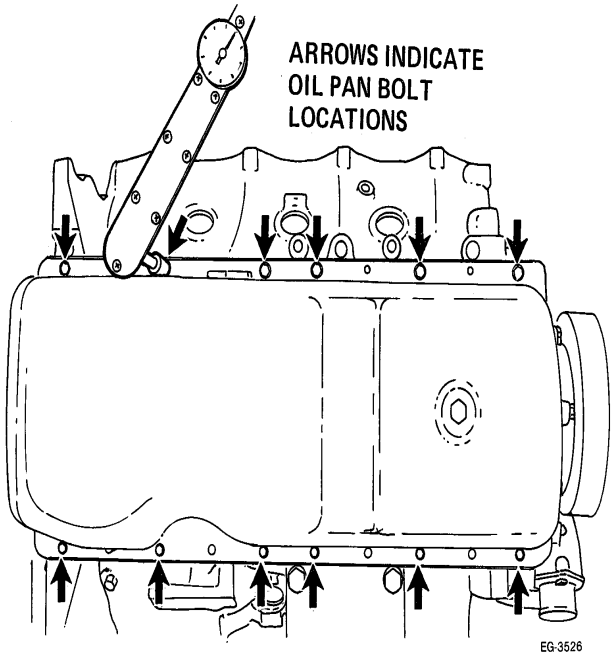
3. Apply Wacker T-95 to the bottom of the crankcase on the inside of the bolt holes. Apply a more liberal amount of RTV at pan radii locations identified with arrows.



⚠CAUTION

Do not apply excessive amounts of RTV which could end up in the pick-up screen, restricting lube oil flow.

4. Install guide studs at two places on the crankcase to assure proper oil pan alignment. Install oil pan onto crankcase within 10 minutes of Wacker T-95 RTV application.
5. Install mounting bolts finger tight; remove guide studs and replace with oil pan mounting bolts. Tighten bolts to specified torque.



Valve Train Specifications - Camshaft Hydraulic Valve Lifters and Push Rods

Camshaft

Bearing Journal Diameter (All Journals)	2.099 - 2.100 in. (53.31 - 53.34 mm)
Bearing (Bushing) Diameter	2.102 - 2.105 in. (53.39 - 53.48 mm)
Journal/Bushing Running Clearance	0.002 - 0.006 in. (0.051 - 0.165 mm)
Shaft End Play	0.002 - 0.008 in. (0.051 - 0.203 mm)
Timing Gear Backlash	0.0055 - 0.0101 in. (0.140-0.256 mm)
Maximum Permissible Cam Lobe Wear	0.020 in. (0.51 mm)
Journal Surface Finish	16 RMS
Camshaft Thrust Plate Thickness	
Inside the Thrust Area	0.154 - 0.156 in. (3.910 - 3.960 mm)
Outside the Thrust Area	0.149 - 0.157 in. (3.784 - 3.987 mm)
Camshaft Lobe Lift	
Intake	0.2535 in. (6.44 mm) Max.
Exhaust	0.2531 in. (6.43 mm) Max.
Valve Timing No.1 Cylinder (Top of Ramp)	
Intake Open	17.2° BTDC
Closed	42.8° ABDC
Exhaust Open	51.2° BBDC
Closed	20.8° ATDC

Hydraulic Valve Lifters

Diameter	0.9209 - 0.9217 in. (23.391 - 23.411 mm)
Bore Diameter in Crankcase	0.9228 - 0.9243 in. (23.439 - 23.477 mm)
Clearance in Bore	0.0011 - 0.0034 in. (0.027 - 0.086 mm)
Bleed-down Rate	18 - 90 Sec. for 0.125 in. Travel*

Push Rod

Run Out/Straightness (Max. TIR)	0.02 in. (0.518 mm) Max.

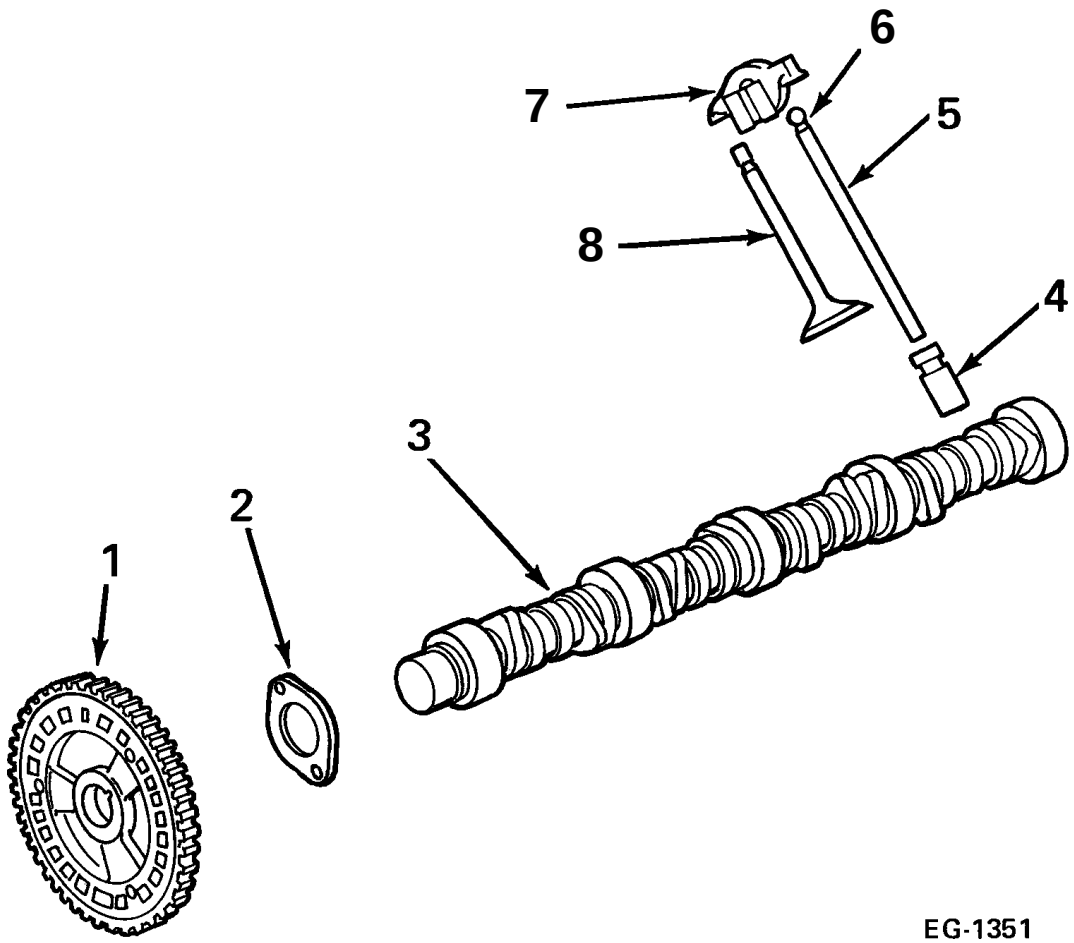
Special Torque Values

Use Standard Torque Values. See end of this section.

Special Service Tools

Tools	Description
ZTSE-1893	Hydraulic Valve Lifter Tester

Camshaft and Related Component - Exploded View



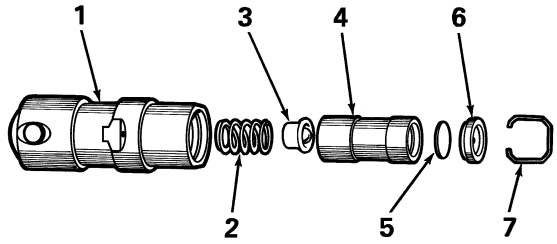
1 - Camshaft Gear
2 - Thrust Plate
3 - Camshaft
4 - Hydraulic Valve Lifter
5 - Valve Push Rod
6 - Copper Colored End
7 - Valve Lever
8 - Valve

Hydraulic Valve Lifters

Operation

Oil, from oil gallery is supplied to the lifter through a hole in the side of the lifter body which indexes with a groove and hole in the lifter plunger. Oil is then metered past the oil metering valve, through the push rods and onto the valve levers.

When the lifter begins to roll up the cam lobe, the check valve is held against its seat in the plunger by the check valve spring which traps the oil in the base of the lifter body below the plunger. The plunger and lifter body then raise as a unit, pushing up the push-rod to open the valve. The force of the valve spring which is exerted on the plunger through the valve lever and push rod causes a slight amount of leakage between the plunger and lifter body. This “leak-down” allows a slow escape of trapped oil in the base of the lifter body. As the lifter rides down the other side of the cam lobe and reaches the base circle or “valve closed” position, the plunger spring quickly moves the plunger back (up) to its original position. This movement causes the check valve to open against the check valve spring and oil is replenished from the oil gallery. This restores the lifter to zero lash.

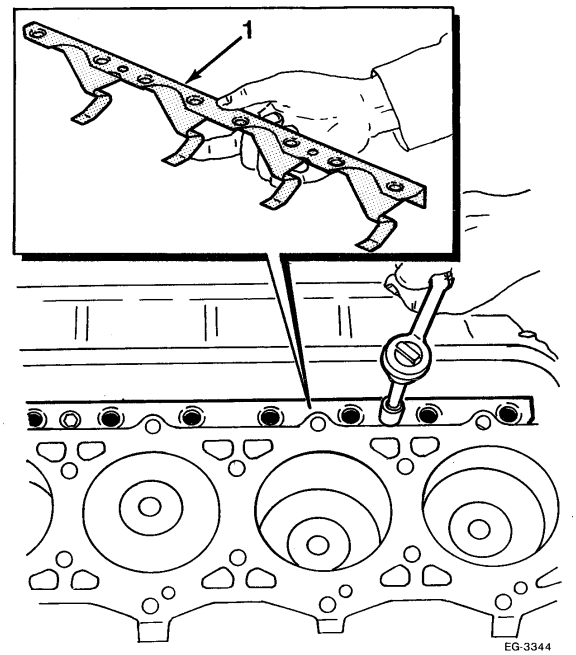


1 - Lifter Body w/Roller
2 - Plunger Spring
3 - Plunger
4 - Plunger Body
5 - Metering Valve
6 - Push Rod Seat
7 - Retainer

NOTE: *Valve lifters and push rods should be kept in order so they can be re-installed in their original position.*

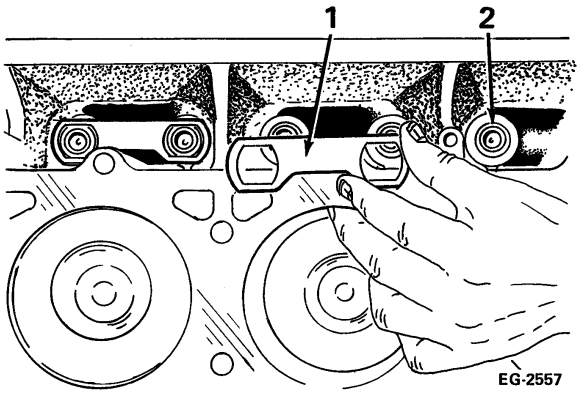
Removal

1. Remove two (2) bolts securing valve lifter guide retainer to crankcase. Remove valve lifter guide retainer



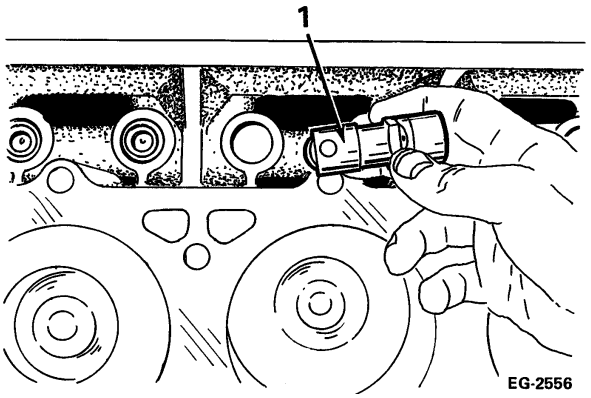
1 - Valve Lifter Guide Retainer

2. Remove valve lifter guides from crankcase.



1 - Valve Lifter Guide
2 - Valve Lifter

3. Remove hydraulic valve lifters from crankcase.



1 - Valve Lifter

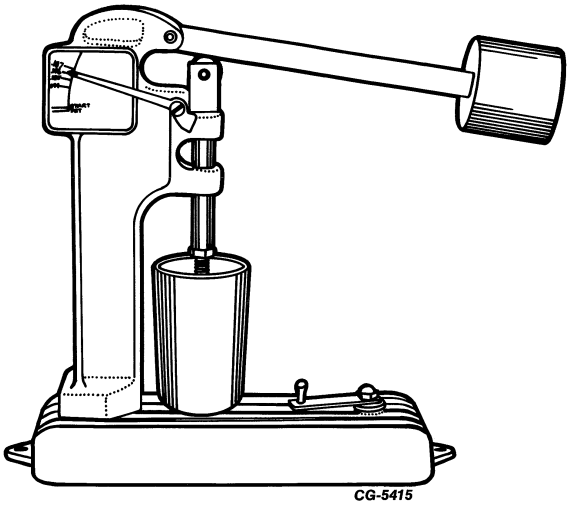
IMPORTANT: Identify hydraulic valve lifter position in relation to cylinder head and bore in crankcase as well as direction of rotation so they can be reinstalled in their original position.

NOTE: *As a general rule, hydraulic valve lifters should not receive service when they are functioning satisfactorily and valve train operates without lifter noise.*

Leakdown Test

This is used to determine whether the leakage past the plunger and lifter body is correct and if the check valve is functioning properly.

1. Use Hydraulic Valve Lifter Tester ZTSE-1893 for checking leak down rate. Follow instructions which accompany tester

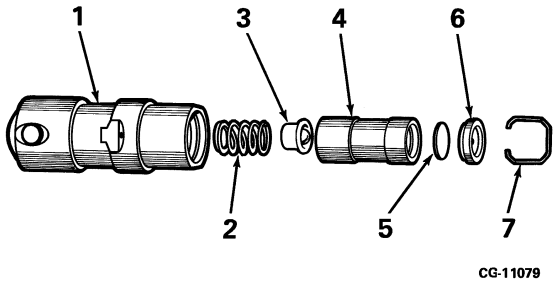


2. Leakdown or bleed-down rate is time in seconds for plunger to move a specified distance of its travel while under a 50 lb. load. Refer to **"SPECIFICATIONS**".

IMPORTANT: Use test fluid specified by tool manufacturer with fluid at room temperature.

DISASSEMBLY

1. Remove push rod seat retainer using a small screwdriver.
2. Remove push rod seat and metering valve.
3. Remove plunger, plunger body, and plunger spring.



1 - Lifter Body w/Roller
2 - Plunger Spring
3 - Plunger
4 - Plunger Body
5 - Metering Valve
6 - Push Rod Seat
7 - Retainer

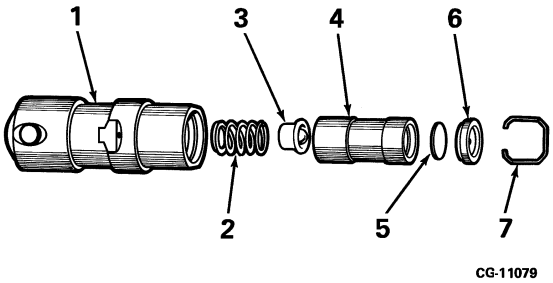
Cleaning and Inspection

1. Immerse all parts in clean solvent. Remove and dry.
2. Visually inspect all disassembled parts for nicks, burrs or scoring. If signs of damage are visible, replace the entire hydraulic valve lifter.
3. **IMPORTANT!** Check lifter body with rollers as follows:
   a. While pushing on the roller in normal direction of load, examine for free rotation of roller and examine axial movement between pin and roller.
   b. Visually inspect roller for pits or roughness.
   c. If a roller fails any one of the preceding inspection criteria. **YOU MUST INSPECT THE CAMSHAFT LOBES FOR DAMAGE.**

IMPORTANT: The roller on the valve lifter is crowned by design. therefore, a normal wear pattern will typically be centered on the roller contact surface.

REASSEMBLY

1. Coat all hydraulic valve lifter parts with clean engine oil.
2. Install plunger spring and plunger into plunger body and then into lifter body.
3. Install metering valve and push rod seat into lifter, install retaining ring.



1 - Lifter Body w/Roller
2 - Plunger Spring
3 - Plunger
4 - Plunger Body
5 - Metering Valve
6 - Push Rod Seat
7 - Retainer

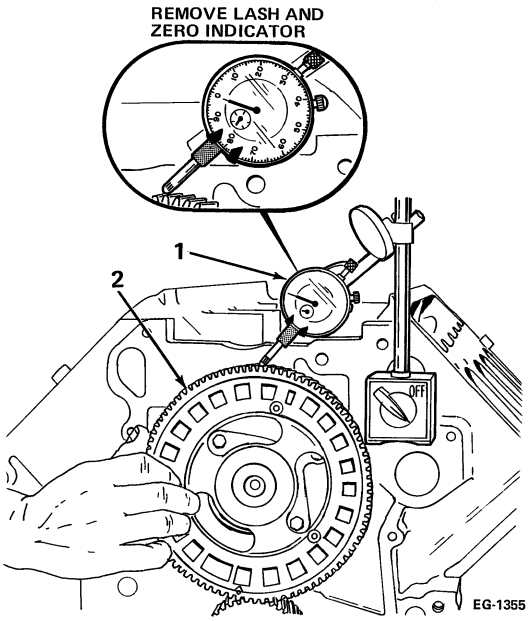
NOTE: *After reassembly, perform a leakdown test to assure that leakage past the plunger and lifter body is correct and to assure that the check valve is functioning properly.*

Camshaft And Gear

Removal

NOTE: *Check valve lifters for wear prior to any camshaft replacement.*

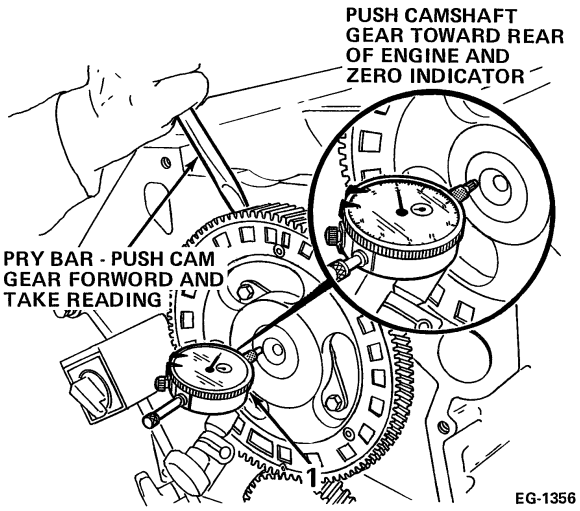
1. Prior to camshaft removal, mount dial indicator on front of engine; check and record camshaft gear-to-crankshaft gear backlash. If backlash exceeds specified limits (see **SPECIFICATIONS**) timing gears should be replaced.



1 - Dial Indicator
2 - Camshaft Gear

   a. Position dial indicator tip on a gear tooth and remove lash.
   b. Zero dial indicator.
   c. Rotate gear by hand and read indicator. Record backlash.

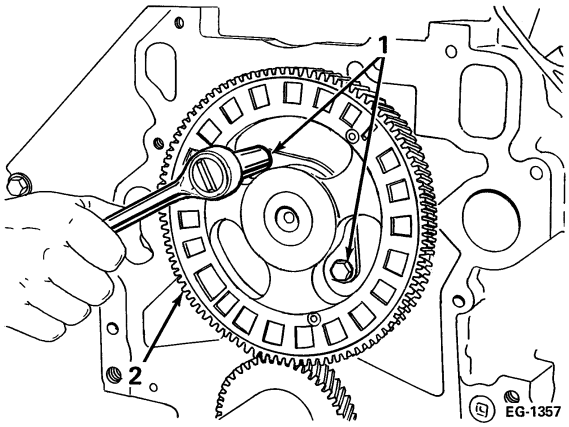
2. Reposition dial indicator and check camshaft end play as follows:



1 - Dial Indicator

   a. Push camshaft toward rear of engine.
   b. Zero dial indicator.
   c. Place a small pry bar between camshaft gear and crankcase. Lightly pry camshaft forward. Compare dial indicator reading with specifications.
   d. Remove dial indicator.

e. If end play exceeds specified limits, (see **"SPECIFICATIONS"**), replace camshaft thrust plate.



1 - Cam Gear Thrust Plate Bolts
2 - Cam Gear

3. Remove two (2) cam gear thrust plate bolts.
4. With engine on mounting stand [Front end in a vertical position], remove camshaft as follows:

NOTE: *The camshaft can be removed with cylinder heads and valve lifters in place. Refer to the appropriate sections for removal of oil pan, valve train and front cover, then proceed as follows:*

a. With engine mounted in a horizontal position, remove valve covers, valve cover gaskets with UVC harnesses. Remove valve levers and push rods keeping parts in order for reassembly in original locations.

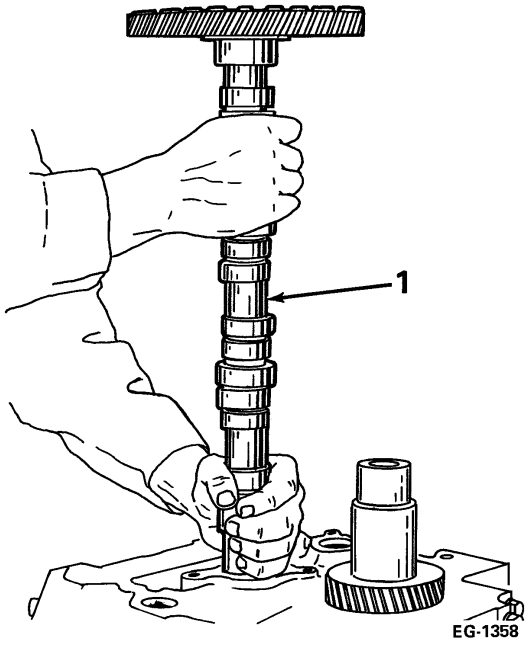
b. Rotate engine in stand to front up vertical position.

c. Remove oil pan, oil pick-up tube and front cover.

d. Rotate crankshaft 2 complete turns to allow camshaft to push the valve lifters away from the lobes.

e. Remove cam retainer flange bolts and carefully lift camshaft and gear assembly from engine.

f. Lift camshaft w/gear from crankcase.



1 - Camshaft Assembly

IMPORTANT: Do not disturb the engine in its vertical position while the camshaft is out, because the lifters could move or fall out of their bores. should this happen it is necessary to remove the cylinder heads to reinstall the lifters.

GEAR REMOVAL

NOTE: *The camshaft gear is assembled to the camshaft with a shrink fit and should only be removed with a hydraulic press.*

Cleaning and Inspection

1. Wash camshaft in cleaning solvent with a soft brush.
2. Visually inspect camshaft. If any lobes are scuffed, scored or cracked, replace camshaft.

NOTE: *This engine utilizes hydraulic valve lifters with roller followers. Therefore, a lifter guide is needed to maintain proper roller to cam lobe orientation. Normal clearance between the valve lifter and guide allows slight tracking of roller across cam lobe. This tracking of valve lifter roller is a normal characteristic as the roller accelerates and decelerates during typical engine operation. Consequently, a typical wear pattern on the cam lobes will exhibit tracks from side to side and have wide and narrow areas from the loading and unloading of the follower. The visual wear pattern (tracking) is normal and does not require camshaft replacement.*

3. Beyond visual inspection, evaluate camshaft journal and lobe condition using a micrometer as follows:

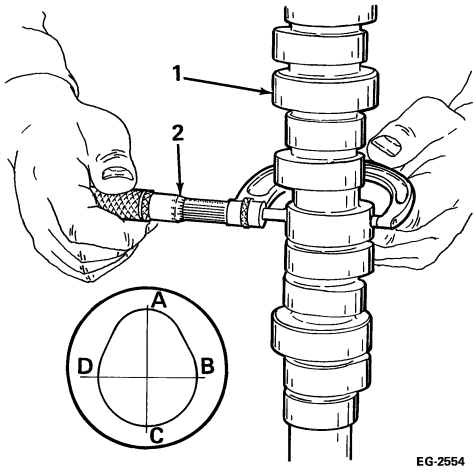
   a. Inspect camshaft journals for wear. Using a micrometer, measure camshaft journal diameter (see **SPECIFICATIONS**). If journals are worn beyond limits, replace the camshaft.

   b. Check camshaft lobe wear using a micrometer as follows:

      Measure across (A-C) and across (B-D).

      Subtract (B-D) from (A-C). This will give cam lobe lift. (See **SPECIFICATIONS).**

Replace camshaft when cam lobe wear exceeds **"SPECIFICATIONS"**.

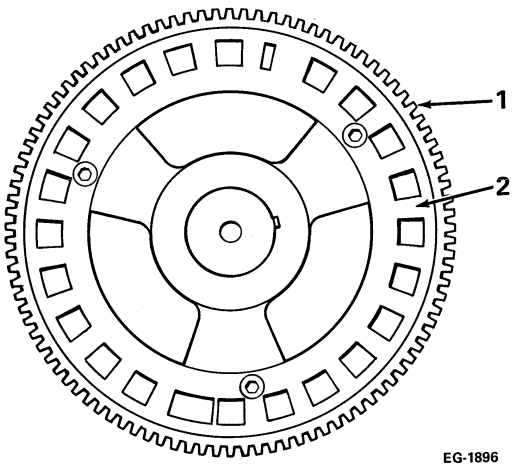


1 - Camshaft
2 - Micrometer

4. Visually insect thrust plate for wear, cracks or distortion. Use a micrometer to measure thrust plate thickness. (See **SPECIFICATIONS**). Replace thrust plate if worn or damaged.

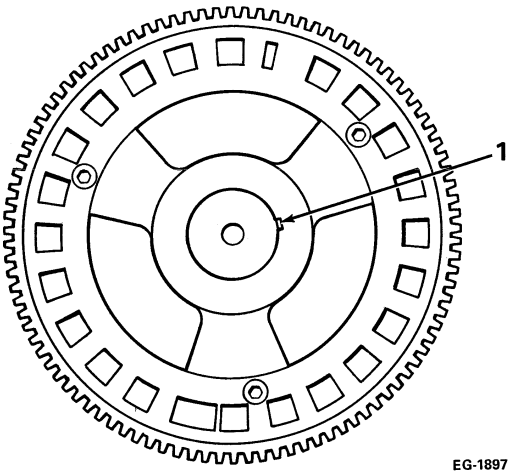
5. Visually inspect camshaft drive gear for worn or damaged teeth. Inspect the CMP timing disk attached to the front face of the cam gear. If either of these components are worn or damaged the gear and timing disk must be replaced as an assembly.

The replacement cam gear and timing disk assembly has been accurately timed by the factory. **DO NOT DISASSEMBLE THESE COMPONENTS AS ACCURATE TIMING UPON REASSEMBLY CANNOT BE ASSURED.**



1 - Cam Gear
2 - Timing Disk

Heat the cam gear and timing disk assembly in an oven to 500° F (260° C). While the assembly is heating, position the camshaft vertically near the oven. Clean the nose of the camshaft, install the flange on its journal and install the cam gear key in its slot.



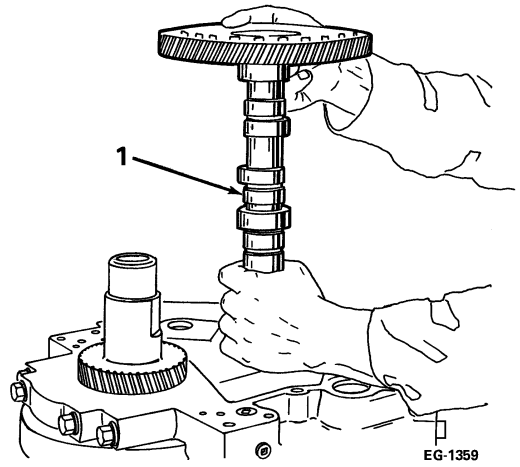
1 - Cam Gear Key

Remove the cam gear assembly from the oven, quickly align gear keyway with key and position gear assembly over the nose of the camshaft until the gear is seated against the retaining flange shoulder. Allow assembly to cool **(DO NOT QUENCH**) before attempting installation of camshaft in engine.

CAMSHAFT INSTALLATION

1. Coat camshaft lobes and bushing journals with clean engine oil.

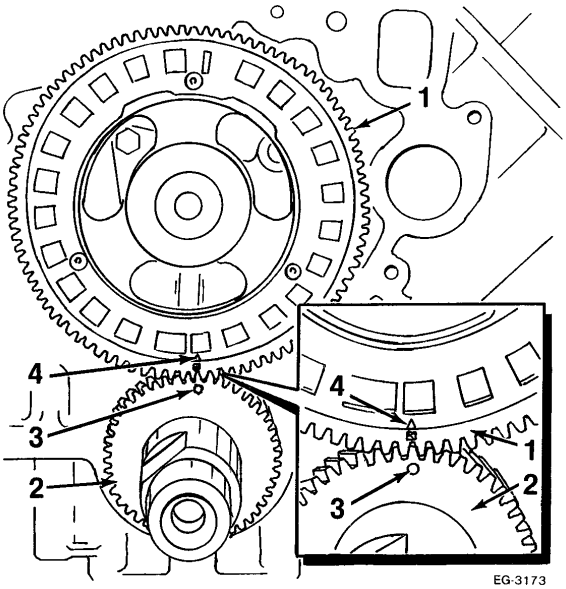
2. Position crankcase with front face up on engine stand and carefully install camshaft assembly.



1 - Camshaft

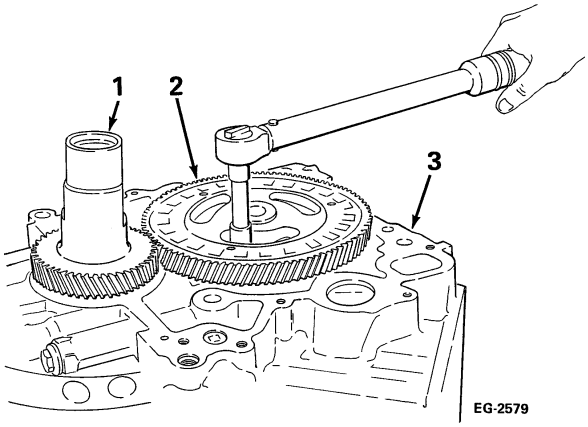
IMPORTANT: Be sure to avoid nicking or scratching camshaft bushings with cam lobes.

3. Index cam gear and crankshaft gear so that timing marks are aligned when camshaft is in place.



1 - Cam Gear
2 - Crankshaft Gear
3 - Crankshaft Gear Timing Mark
4 - Cam Gear and Timing Disk Marks

4. Install two thrust plate mounting bolts and tighten to specified torque.



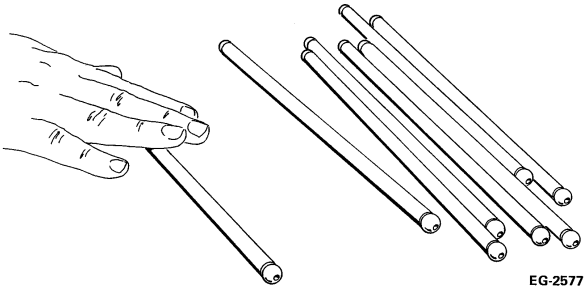
1 - Crankshaft
2 - Camshaft Gear
3 - Crankcase

IMPORTANT: If new parts are installed, confirm that gear backlash and end play are within specifications.

CLEANING AND INSPECTION OF PUSH RODS

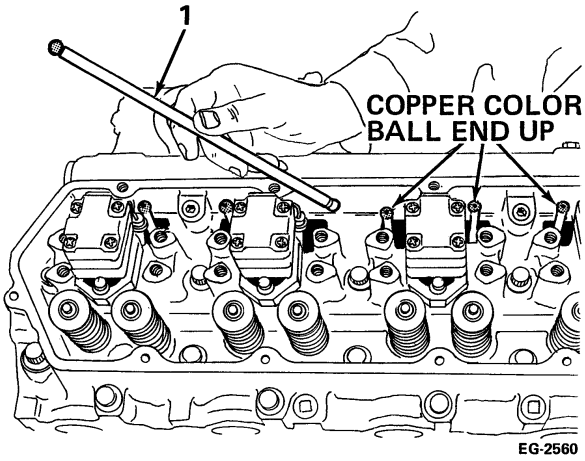
NOTE: *The push rods are hollow and serve as oil galleries to lubricate each individual rocker arm assembly.*

1. Thoroughly clean each push rod using a suitable solvent and dry using filtered compressed air.
2. Visually inspect each rod for wear and deposits which may restrict the flow of oil into the valve lever assemblies. Replace as required.
3. Check all push rods for straightness by rolling on a flat surface. If straightness is questionable refer to specifications for runout. If **SPECIFICATIONS** are exceeded, replace the push rod.



INSTALLING PUSH RODS

1. Insert push rods in their respective positions with copper colored end up.



1 - Push Rod

IMPORTANT: The two ball ends of the push rods are different materials to ensure the compatibility of metallic mating surfaces of the valve lever, push rod and valve lifter. Copper colored end must be installed up.

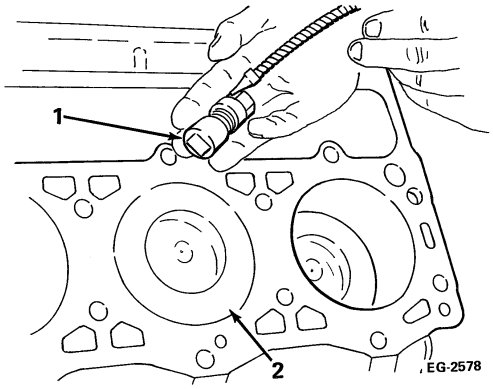
NOTE: *On higher mileage engines, cleaning push rods is necessary to identify the copper colored ball end. The copper colored ball end will exhibit a shiny/polished pattern on the upper half (180°) of the ball and the lower half will appear more tarnished/blackened than the original copper color. The bottom/lifter end of the push rod will appear totally polished and shiny.*

Valve Train

REASSEMBLY

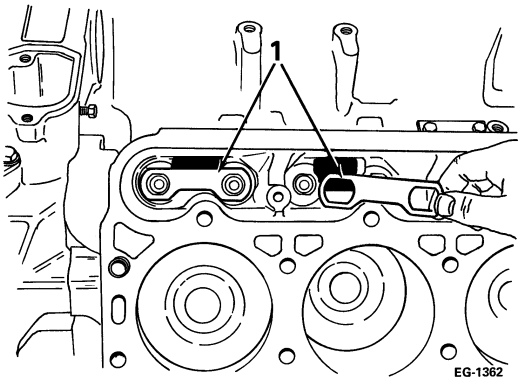
NOTE: *Assure all parts are clean prior to reassembly and lubricate all parts with clean engine oil.*

1. Install hydraulic valve lifters into their respective lifter bores in cylinder block. Maintain original direction of rotation.



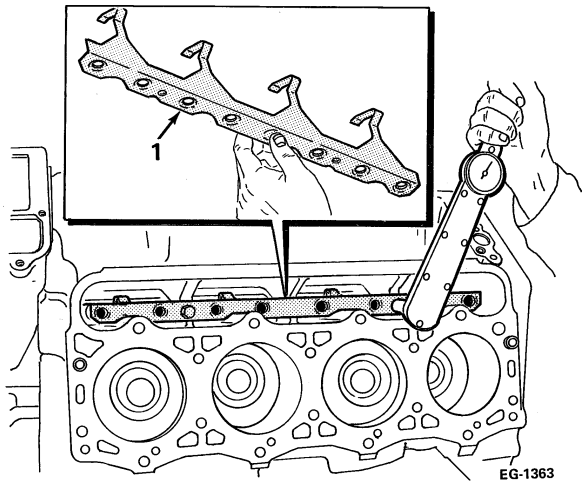
1 - Hydraulic Valve Lifters
2 - Piston

2. Install valve lifter guides over hydraulic valve lifters.



1 - Valve Lifter Guide

3. Install valve guide retainer and fasten using two (2) retainer bolts. Tighten to Standard Torque.



1 - Valve Guide Retainer

Specifications - Crankcase, Camshaft Bushings, Crankshaft & Bearings, Flywheel, Connecting Rods, Pistons & Rings

Crankshaft

Main Bearing Journal Diameter	
Standard Size	3.1228 - 3.1236 in. (79.319 - 79.340 mm)
.010” Undersize	3.1128 - 3.1136 in. (79.065 - 79.085 mm)
.020” Undersize	3.1028 - 3.1036 in. (78.811 - 78.831 mm)
.030” Undersize	3.0928 - 3.0936 in. (78.557 - 78.577 mm)
Main Bearing Journal Max. Out-of-Round	00022 in. (.0056 mm)
Main Bearing Thrust Face Runout (TIR Max.)	.001 in. (.025mm)
Main Bearing Journal Taper (Max./In.)	.00015 in. (.0038 mm)
Main Journal Fillet Radius, Journal No. 1, 2, 3, and 4	0.130 in. (3.30 mm)
Main Journal Fillet Radius, Journal No. 5	0.157 - 0.163 in. (3.99 - 4.14 mm)
Rod Journal Fillet Radius	0.145 in. (3.68 mm)
Oil Seal Journal Runout (Max.)	0.002 in. (0.05 mm)
Damper Mounting Area Runout (Max.)	0.001 in. (0.03 mm)
Flywheel Mounting Surface Runout (Max.)	0.002 in. (0.05 mm)
Number of Main Bearings	5
Thrust Taken By	No. 5 Main
Thrust Bearing Journal Length	1.2405 - 1.2435 in. (31.509 - 31.585 mm)
Main Bearing I.D. (Installed)	3.1254 - 3.1274 in. (79.385 - 79.436 mm)
Main Bearing to Crankshaft Running Clearance	0018 - .0046 in. (.046 - .117 mm)
Main and Rod Bearing Journal Finish	10 RMS
Main Bearing Thrust Face Finish	20 RMS
Connecting Rod Journal Diameter	
Standard Size	2.498 - 2.499 in. (63.45 - 63.47 mm)
.010” Undersize	2.488 - 2.489 in. (63.20 - 63.22 mm)
.020” Undersize	2.478 - 2.479 in. (62.94 - 62.96 mm)
.030” Undersize	2.468 - 2.469 in. (62.69 - 62.71 mm)
Connecting Rod Journal Max. Out-of-Round	00022 in. (.0056 mm)
Connecting Rod Journal Taper (Max./In.)	00026 in. (.0066 mm)
Connecting Rod Bearing to Crankshaft	
Running Clearance	0.0015 - 0.0045 in. (0.038-0.114 mm)
Crankshaft Flange O.D	4.372 - 4.376 in. (111.05 - 111.15 mm)
Crankshaft End Play	0.0025 - 0.0085 in. (0.063 - 0.216 mm)
Crankshaft End Play Max. Wear Limit	.020 in. (.51 mm)
Rod to Crankshaft Side Clearance	0.012 - 0.024 in. (0.30 - 0.61 mm)
Crankshaft Straightness (TIR Max.)	004 in. (.10 mm)

Crankshaft

Crankshaft Gear Backlash	.0055 - .0101 in. (.140 - .256 mm)
Flywheel Runout	Not Available
Flywheel Concentricity	Not Available

Crankcase

Crankcase Deck Flatness	0.001 in. in 2 inches/ .004 Total (.025 mm in 50.8 mm/.10 mm Total)
Crankcase Deck Finish (Micro Inches)	65 - 125
Crankcase Main Bearing Bore Diameter	3.3152 - 3.3162 in. (84.206 - 84.231 mm)
Crankcase Cam Bearing Bore Diameter	2.2305 - 2.2320 in. (56.655 - 56.693 mm)
Valve Lifter Bore Diameter	0.9228 - 0.9243 in. (23.439 - 23.477 mm)
Valve Lifter O.D.	0.9209 - 0.9217 in. (23.391 - 23.411 mm)
Oil Jet Tube Bore Diameter (Spray Hole Dia.)	0.036 - 0.052 in. (0.91 - 1.32 mm)
Cylinder Bore Taper (Top to Bottom) (Max.)	.003 in. (.076 mm)
Cylinder Bore Diameter.	4.1096 - 4.1103 in. (104.384 - 104.402 mm)
Cylinder Bore Maximum Out-of-Round (Max.)	002 in. (.05 mm)
Cylinder Bore Surface Finish	15-30 RMS
Centerline of Main Bearing Bore to Head Deck	11.328 - 11.332 in. (287.73 - 287.83 mm)
Oil Seals (Front and Rear Seal Face Runout)(with Plates Installed on Engine)	0.015 in. T.I.R. Max. (0.38 mm)
Main Bearings	
Type	Precision Replaceable
Material	Steel Backed Copper/Lead
Thrust Taken By	No. 5 Main
Cap Attachment	4 Bolts per Cap

Connecting Rods

Rod Length Center to Center	7.130 in. (181.10 mm)
Bushing Bore Diameter (Pin End)	1.432 - 1.433 (36.37 - 36.41 mm)
Piston Pin Bushing I.D.	1.3085 - 1.3088 in. (33.235 - 33.248 mm)
Material	I-Beam Section - Steel Forging
Bearing Bore Diameter (Crankshaft End)	2.6905 - 2.6915 in. (68.339 - 68.364 mm)
Maximum Out of Round	0.0005 in. (0.013 mm)
Maximum Taper/Inch	0.0005 in. (0.013 mm)
Connecting Rod Bearing I.D.	2.5005 - 2.5025 in. (63.513 - 63.564mm)

Connecting Rods (Cont.)

Connecting Rod Bearing Running Clearance	0.0015 - 0.0045 in. (0.038 - 0.114 mm)
Connecting Rod Side Clearance	0.012 - 0.024 in. (0.30-0.61 mm)
Connecting Rod Alignment (Max. Total Difference)	
Twist	0.002 in./in. (0.05 mm/in.)
Bend	0.001 in./in. (0.025 mm/in.)
Weight - Complete rod without Bearing	1434 - 1458 g
Pin to Bushing Clearance	0.0004 - 0.0009 in. (0.010 - 0.023 mm)

Pistons

Material	Aluminum Alloy
Skirt Diameter	4.1045-4.1052 in. (104.254-104.272mm)
(Measured 1.684 in. below oil groove, at 90° to the piston pin). Measure only at room temperature 68° F. (20° C)	
Service Piston	
Standard Size	4.10475 ± 0.00025 in. (104.2606±0.0064 mm)
.010” Oversize	4.11475 ± 0.00025 in. (104.5146±0.0064 mm)
.020” Oversize	4.12475 ± 0.00025 in. (104.7686±0.0064 mm)
.030” Oversize	4.13475 ± 0.00025 in. (105.0226±0.0064 mm)
Top Compression Ring Groove Width - Measure over 0.1150 in. gauge pins	
	4.128 in. (104.85 mm) Upper Limit
	4.097 in. (104.06 mm) Replacement Limit
Piston Height Above Crankcase Deck	Not Available
Clearance in Cylinder Bore - Cylinder No. 1 thru 8	0.0044 - 0.00587 in. (0.112 - 0.1491 mm)

Piston Pins

Length	2.99 - 3.00 in. (75.9 - 76.2 mm)
Diameter	1.3079 - 1.3081 in. (33.220 - 33.226 mm)
Pin Fit @ Room Temperature 68° F (20° C)	
Clearance in Rod	0.0004 - 0.0009 in. (0.010 - 0.023 mm)
Clearance in Piston	0.0003 - 0.0007 in. (0.007 - 0.018 mm)
End Clearance	0.004 - 0.030 in. (0.10 - 0.76 mm)

Piston Rings

Ring Diameter (Standard)	
Compression Top [Full Keystone (Barrel Face) Plasma Coated]	4.11 in. (104.4 mm)
Compression 2nd [Rectangular Negative Twist - Tapered Face]	4.11 in. (104.4 mm)
Oil Control [One Piece Conformable w/ Chrome Expander Spring]	4.11 in. (104.4 mm)
Fit in Groove (Side Clearance)	
2nd	0.002 - 0.004 in. (0.05 - 0.10 mm)
Oil Control	0.0009 - 0.0029 in. (0.023 - 0.074 mm)
Ring Gap in Bore	
Top	0.014 - 0.024 in. (0.35 - 0.61 mm)
2nd	0.062 - 0.072 in. (1.57 - 1.83 mm)
Oil Control	0.012 - 0.024 in. (0.30 - 0.61 mm)

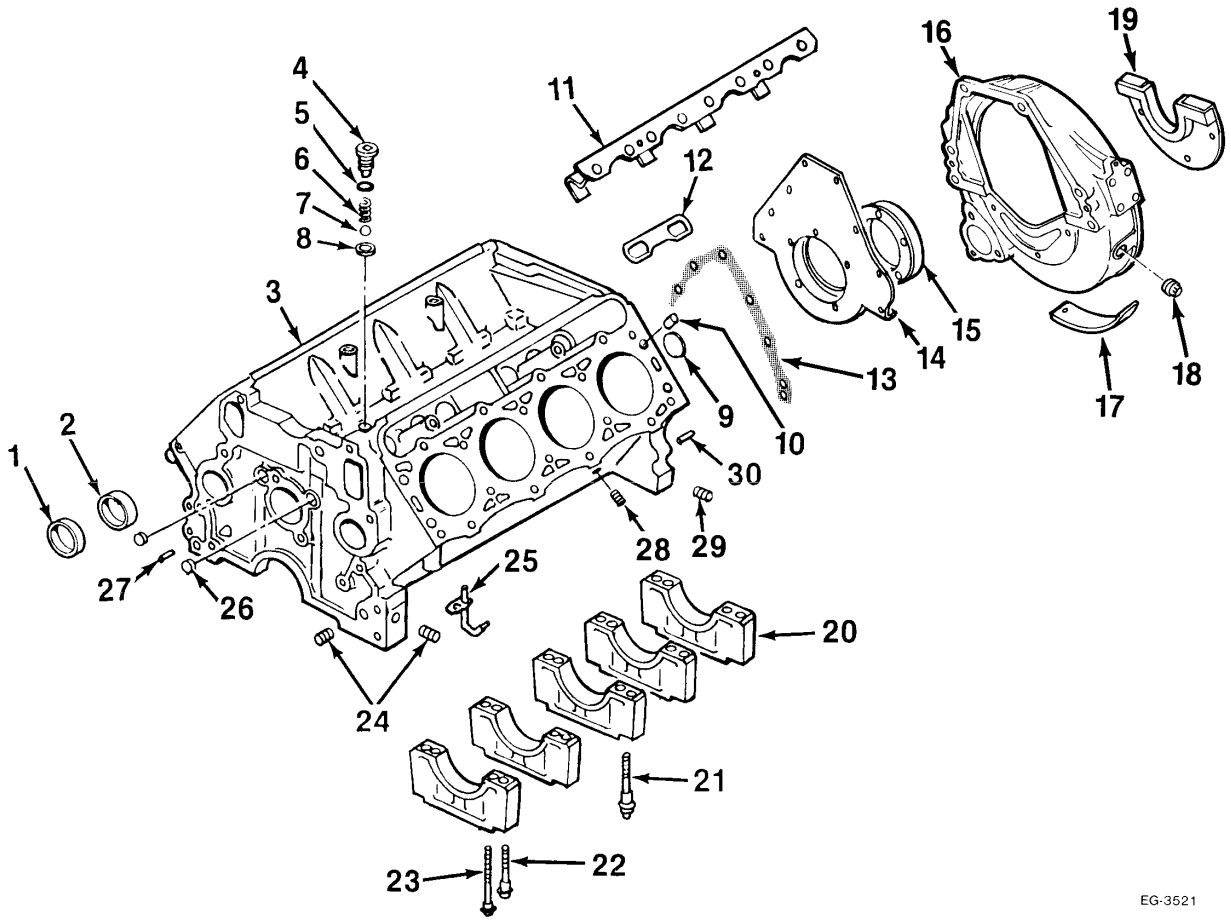
Special Torque Values

Crankshaft Vibration Damper Bolt	212 lb.ft. (287 N·m)
Flywheel Mounting Bolt (See Note 1)	89 lb.ft. (121 N·m)
Main Bearing Cap Bolts (See Note 2)	95 lb.ft. (129 N·m)
Oil Pan Drain Plug	28 lb.ft. (37 N·m)
Rear Cover Mounting Bolts	15 lb.ft. (20 N·m)
Front Cover Mounting Bolts	15 lb.ft. (20 N·m)
Water Pump Mounting Bolts	15 lb.ft. (20 N·m)
Oil Pick-Up Tube Flange Bolts	18 lb.ft. (24 N·m)
Piston Cooling Tube Bolt	100 lbf-in (11 N·m)
Oil Level Gauge Tube Adapter Nut	24 lb.ft. (33 N·m)
Connecting Rod Nuts (First Step)	52 lb.ft. (71 N·m)
Connecting Rod Nuts (Final)	80 lb.ft. (108 N·m)

Special Service Tools

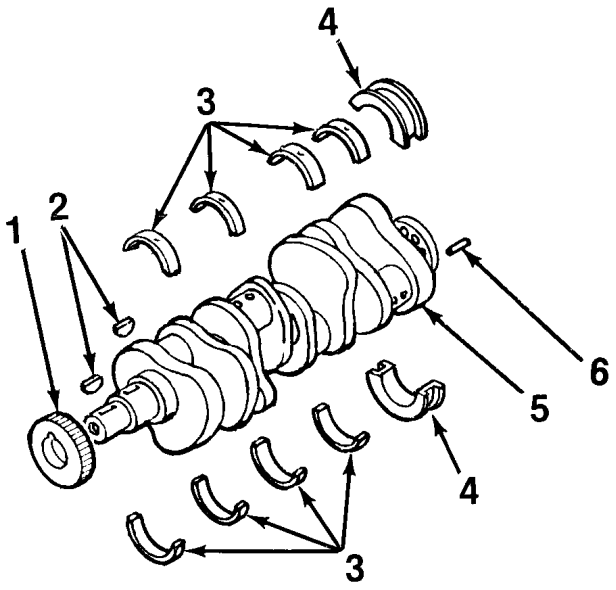
Tool No.	Description
ZTSE-4349	Flex Hone
D81L-6002B	“Plasti-gage”
ZTSE-4309	Crankcase Cup Plug Installer
ZTSE-4311	Rod Guide Caps
ZTSE-2393C	Camshaft Bushing Tools
ZTSE-30201	Keystone Pin Gauges
ZTSE-4310	Front Crankshaft Oil Seal/Damper Installer
ZTSE-4317	Crankshaft Wear Ring Remover
ZTSE-4318	Crankshaft Wear Ring Installer

Crankcase, Front Cover, Flywheel Housing Adapter and Related Parts



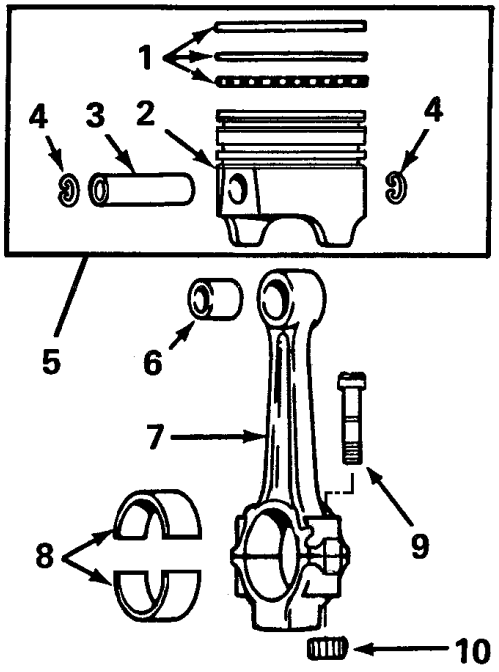
1- Front Camshaft Bushing
2- Camshaft Bushing (2nd, 3rd, 4th and 5th)
3- Crankcase
4- Short Circuit Oil Plug
5- Short Circuit O-Ring
6- Short Circuit Spring
7- Short Circuit Ball
8- Gasket
9- Cup Plug (7)
10- Cylinder Head Guide Dowel Pin
11- Cam Follower Guide Retainer
12- Cam Follower Guide
13- RTV, Liquid Gasket
14- Rear Crankcase Cover
15- Rear Oil Seal
16- Flywheel Housing
17- Flywheel Housing Plate Cover
18- Cap Plug
19- Flywheel Housing Baffle
20- Main Bearing Cap (5)
21- Main Bearing Cap Stud
22- Short Main Bearing Cap Mounting Bolt (10)
23- Long Main Bearing Cap Mounting Bolt (9)
24- Pipe Plug (2)
25- Piston Cooling Tube (8)
26- Cup Plug (2)
27- Dowel Pin (2)
28- Pipe Plug (2)
29- Plug (2)
30- Dowel Pin (2)

Crankshaft Assembly Parts



1- Crankshaft Gear
2- Crankshaft Key (2)
3- Crankshaft Bearings (Nos. 1, 2, 3 and 4)
4- Thrust Bearing No. 5
5- Crankshaft
6- Coiled Spring Pin

Connecting Rods, Pistons and Rings



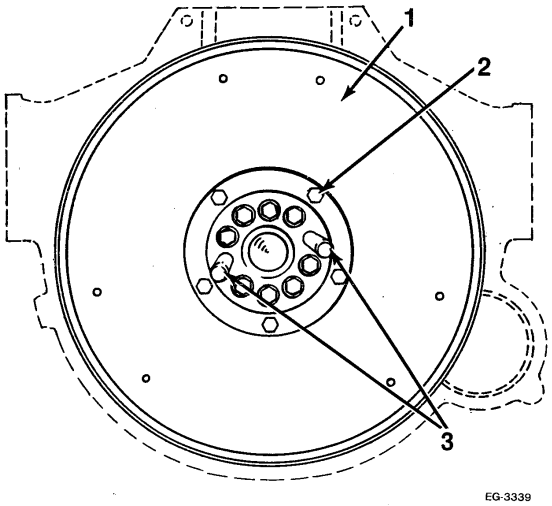
EG-1001

1- Piston Ring Set
2- Piston
3- Piston Pin
4- Retainer Rings
5- Piston Assembly
6- Pin Bushing
7- Connecting Rod
8- Connecting Rod Bearings
9- Connecting Rod Bolts
10- Connecting Rod Nuts

Flywheel and Rear Seal

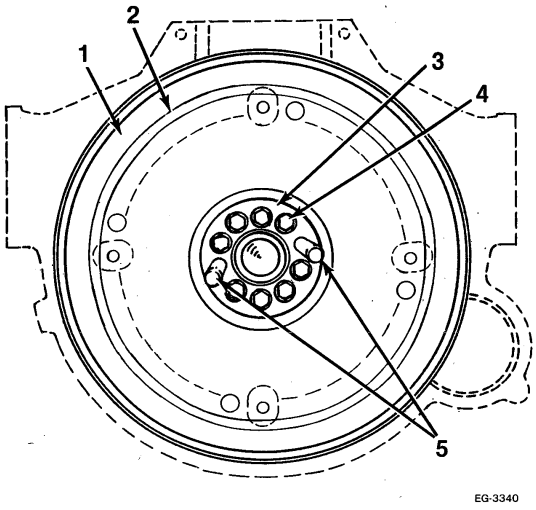
Flywheel Removal

1. Remove two bolts from flywheel and install two guide studs.



1- Flywheel with Ring Gear
2- Flywheel Mounting Bolts (10)
3- Guide Studs

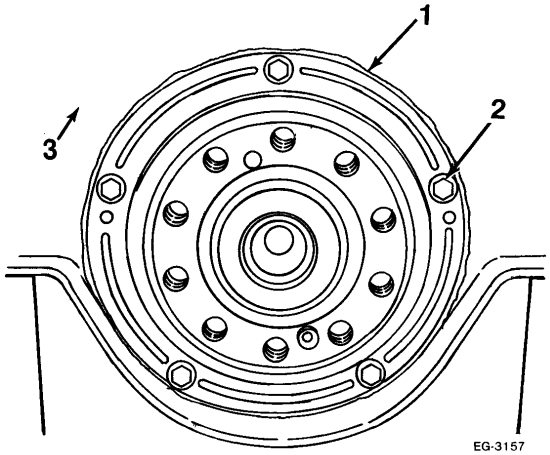
2. Remove remaining flywheel bolts and reinforcement ring then slide flywheel out of housing and off guide studs to remove it from crankshaft. With flywheel removed, the guide studs can be removed from crankshaft flange.



1- Flywheel with Ring Gear
2- Flex Plate
3- Reinforcement Ring Gear
4- Flywheel Mounting Bolts (10)
5- Guide Studs

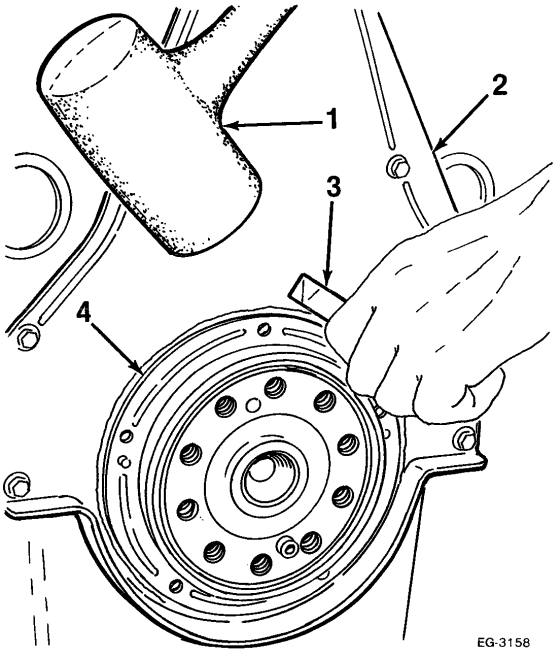
Rear Oil Seal Removal

1. Remove five (5) bolts securing rear oil seal to rear crankcase cover.



1- Seal /Retainer
2- Seal/Retainer Mounting Bolts (5)
3- Rear Crankcase Cover

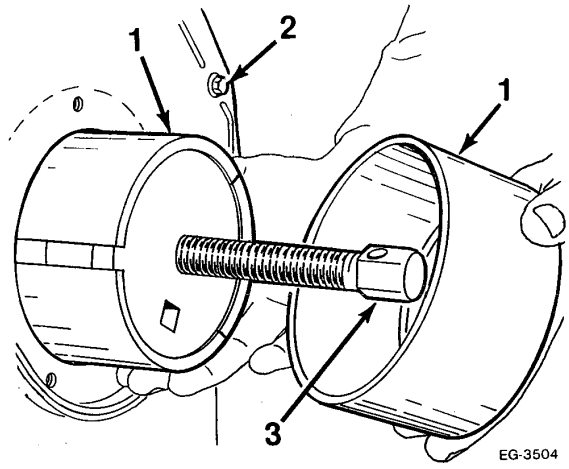
2. Cut through RTV on rear oil seal using tool **ZTSE4385**.



1- Hammer
2- Rear Crankcase Cover
3- RTV Cutting Tool
4- Seal/Retainer

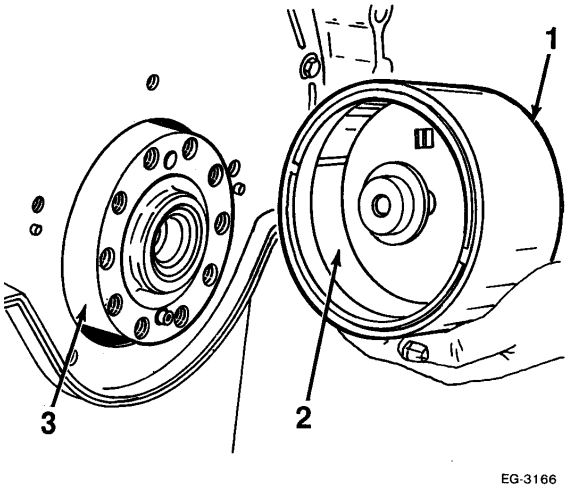
WEAR SLEEVE REMOVAL

1. Remove old wear sleeve as follows:



1- Wear Sleeve Removal Tool
2- Rear Crankcase Cover
3- Forcing Screw

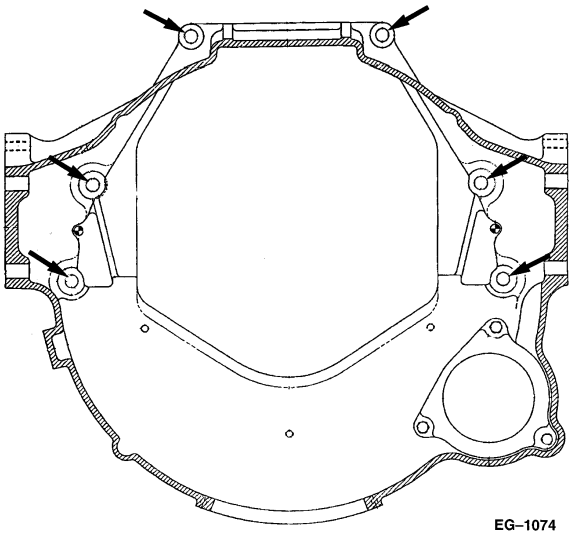
   a. Mount service tool **ZTSE4317** around wear sleeve on crankshaft flange.
   b. Turn forcing screw to remove wear sleeve.
   c. Discard wear sleeve and inspect crankshaft flange for damage.



1- Wear Sleeve Tool
2- Wear Sleeve
3- Crankshaft

Flywheel Housing Removal

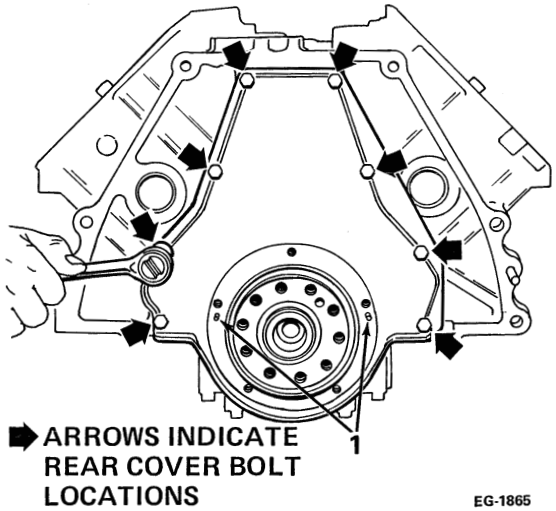
1. Remove the flywheel housing flange bolts and slide housing off of crankcase dowels.



REAR COVER REMOVAL

NOTE: *Rear seal must be removed before removing rear cover.*

1. Remove crankcase rear cover retaining bolts. Gently pry rear cover away from crankcase to break RTV seal. Avoid bending rear plate.



1- Dowel Pins

2. Clean crankcase and rear cover gasket surfaces of all foreign material. Scrape or wire brush RTV sealant from rear cover oil pan mating surfaces. Surfaces must be kept oil free for good adhesion of fresh RTV sealant (during reassembly). Use a commercially available brake cleaner to clean crankcase and rear cover gasket surfaces of oil. Wipe and dry with a clean shop cloth.

NOTE: *If dowel pins are damaged or missing, replace prior to installation of rear plate. If rear cover's dowel holes are damaged or cover is bent, replace with new cover.*

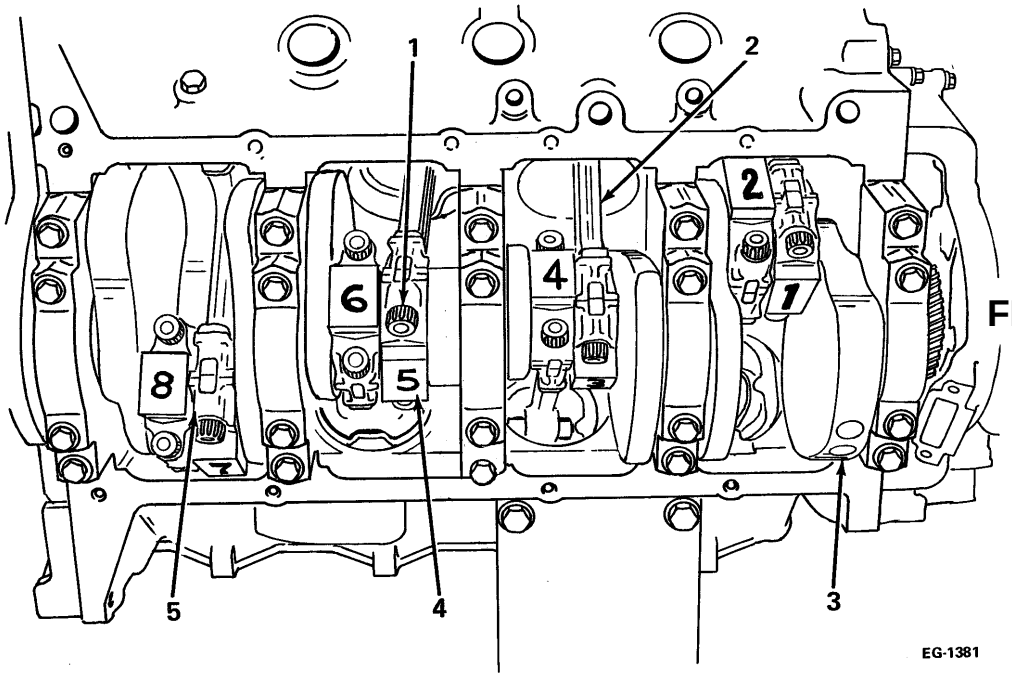
Connecting Rods, Pistons And Rings (Removal)

Disassembly

1. Rotate crankshaft to position journals for removal of connecting rod assemblies.

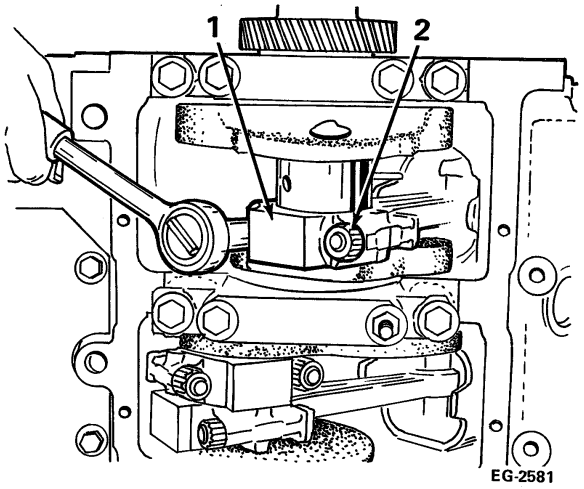
NOTE: *Connecting rod locations may be marked at this time.*

IMPORTANT: If a carbon ridge is evident at top of cylinder bore, remove with an emery cloth or razor knife, prior to removing piston assembly. Do not use a ridge reamer.



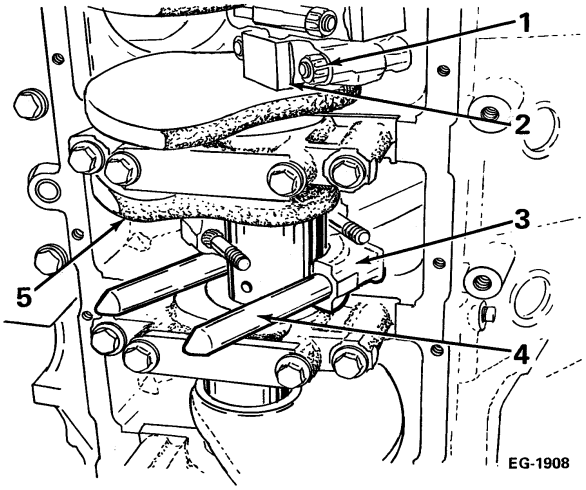
1- Connecting Rod Nuts (16)
2- Connecting Rod (8)
3- Crankshaft
4- Connecting Rod Location Mark
5- Connecting Rod Cap (8)

2. Remove two connecting rod retaining nuts and remove connecting rod cap.



1- Connecting Rod Cap
2- Connecting Rod Nut

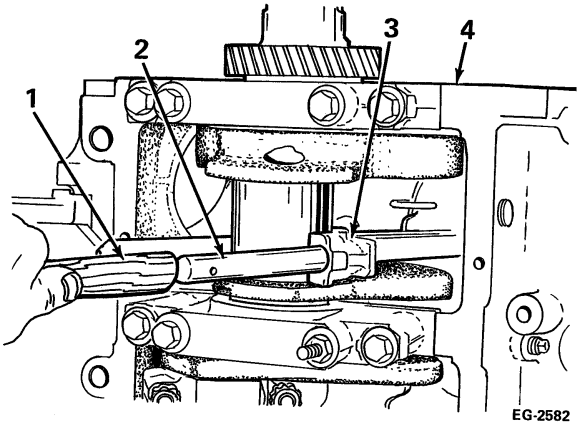
IMPORTANT: Remove cap and install aluminum connecting rod guide protector caps (ZTSE-4311) over connecting rod bolts. This prevents damage to crankshaft journals.



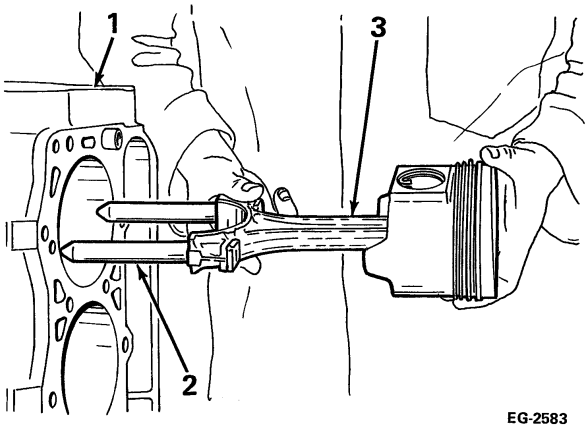
1- Connecting Rod Nut (16)
2- Connecting Rod Cap (8)
3- Connecting Rod (8)
4- Connecting Rod Protector Caps (ZTSE-4311)
5- Crankshaft

NOTE: *Use care when removing piston assembly to prevent component damage.*

3. Using a wooden end of a hammer, gently tap on the protector cap and push connecting rod and piston assemblies from cylinder bore.



1- Wooden Handle
2- Protector Cap
3- Connecting Rod
4- Crankcase



1- Crankcase
2- Protector Cap
3- Connecting Rod

NOTE: *Replace cap and bearing inserts on connecting rod so identification codes match.*

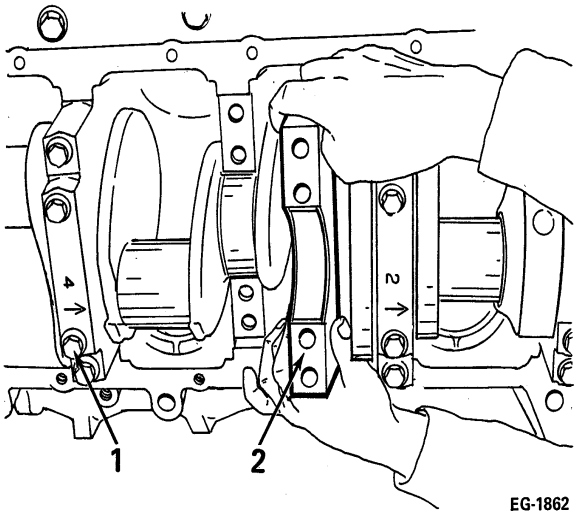
Damper, Crankshaft And Main Bearing (Reconditioning)

Removal (For Engine Overhaul)

CRANKSHAFT AND MAIN BEARINGS

NOTE: *Crankshaft bearing caps are numbered from front to identify their respective positions for reinstallation. The number 5 bearing cap accommodates a thrust flange to limit crankshaft end play.*

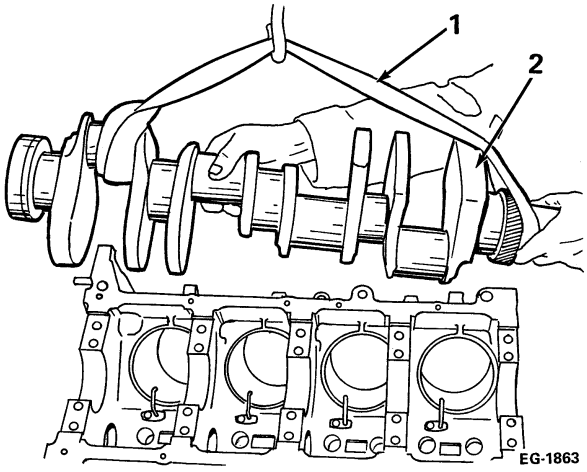
1. Remove main bearing cap bolts. Lift main bearing caps from crankshaft journal.



1- Main Bearing Cap Bolt
2- Main Bearing Cap

NOTE: *Loosen bearing caps by rocking back and forth. Thrust Bearing (Rear Bearing) can be loosened by rocking from side to side.*

2. Remove lower bearing shell from cap and keep in order for inspection.
3. Attach lifting sling to crankshaft and lift crankshaft straight up and out of crankcase.



1- Lifting Sling
2- Crankshaft

IMPORTANT: Be careful not to damage the crankshaft when removed.

4. With crankshaft removed, remove upper main bearing inserts by pushing them out of the main bearing saddle. Mark upper shells and put them with lower shells so that a proper inspection can be done.

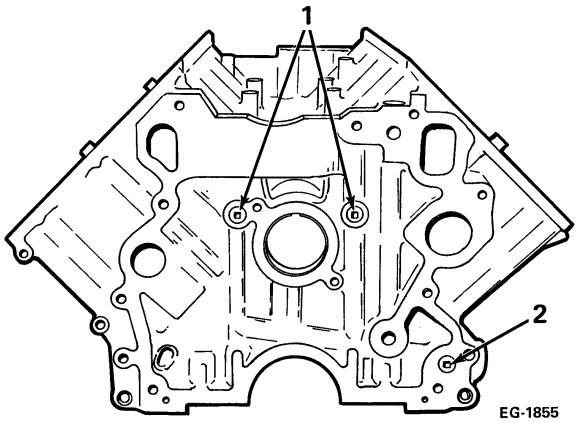
Crankcase (Reconditioning)

Cleaning

NOTE: *The best way to clean crankcase during engine overhaul is in a chemical bath or HOT TANK. This removes all carbonaceous material and mineral deposits which collect in the cooling passages. However, when a HOT TANK is not available, use the following cleaning procedures.*

IMPORTANT: Thoroughly clean and inspect crankcase before and after reconditioning.

1. Clean all old gasket material from machined surfaces of crankcase, using a scraper. Clean cylinder bore using soap, water and a nylon brush.
2. Remove pipe plugs (located in front of crankcase) which seal oil passages and thoroughly clean all passages and bolt holes.
3. Remove main oil gallery plug and use a nylon bore brush to clean main oil gallery.

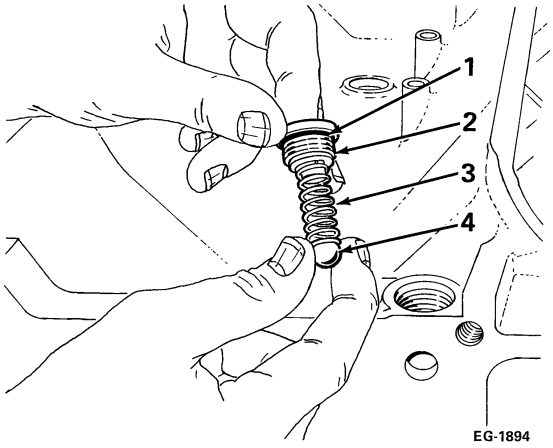


1- Valve Lifter Gallery Plugs
2- Main Oil Gallery Plug

4. Remove valve lifter oil gallery cup plugs located in rear of crankcase. Clean valve lifter oil galleries with a nylon brush. Replace valve lifter gallery cup plugs flush to 0.060” (1.52 mm) below crankcase surface.

NOTE: *Use Aviation Permatex No. 3 prior to installing main and valve lifter oil gallery plugs. The main oil gallery plug must be installed below flush with the crankcase.*

5. Remove oil plug (located in top front of crankcase) with an Allen wrench. Remove and inspect the spring and ball for wear. Install items after cleaning crankcase.



1- O-Ring
2- Sealing Plug
3- Spring
4- Check Ball

Crankcase Cup Plugs

1. To remove a cup plug use a punch and hammer near the edge of the plug and strike with a hammer. Remove from crankcase.
2. Install new cup plugs. Coat edges of plug with Aviation Permatex No. 3. Use cup plug driver **ZTSE4309**.

NOTE: *The cup plug driver tool installs the cup plug to the proper depth.*

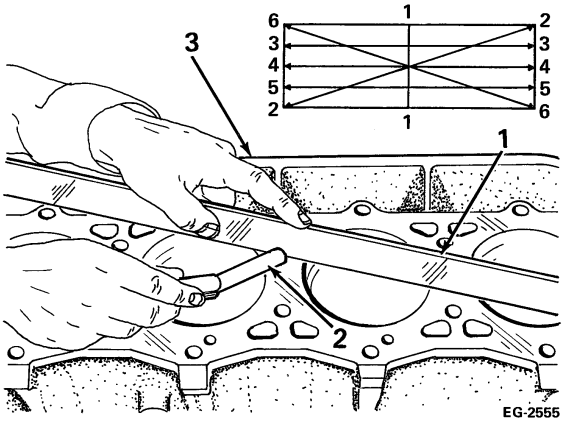
Inspection And Repair

IMPORTANT: Threads in crankcase bolt holes must be clean and blown dry with filtered compressed air. Dirt or oil in holes may cause binding and/or false torque reading during reassembly.

1. Visually inspect crankcase, after cleaning, for scoring, roughness or wear at cylinder bores. Also check for cracks.

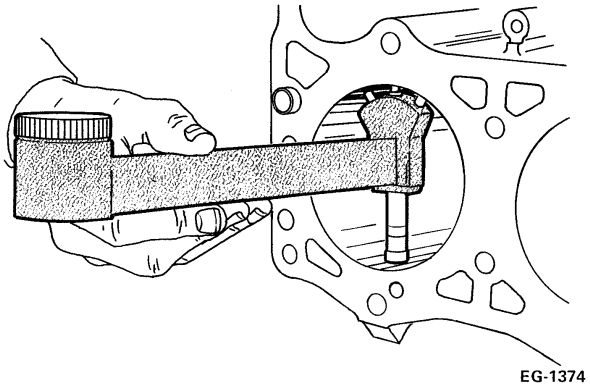
Replace crankcase if cracked; do not attempt to weld.

2. Check top surface of crankcase for flatness. Using a straightedge, check by attempting to insert a .004 in. (0.10 mm) feeler gauge between straightedge and crankcase head surface. If gap exceeds .004 in. (0.10 mm), crankcase must be replaced.

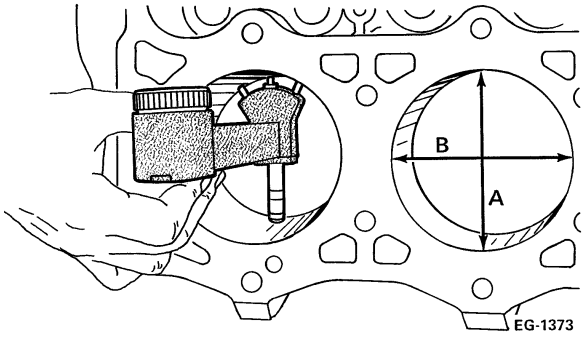


1- Straightedge
2- Feeler Gauge
3- Crankcase

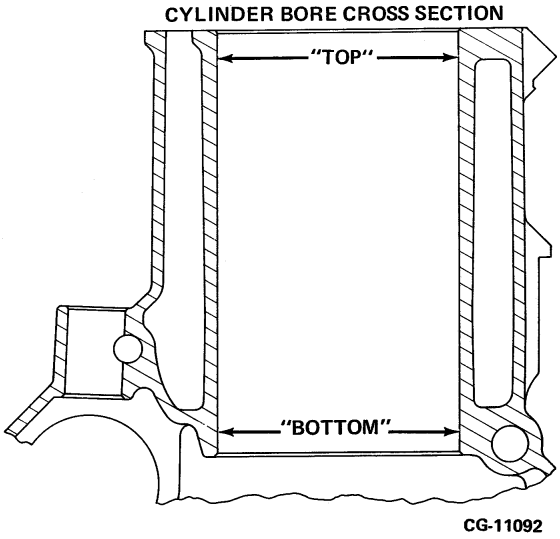
3. Check cylinder bore out-of-round and taper using a dial bore gauge.



4. Measure diameter of cylinder bore at top of piston ring travel at a right angle “A” to center- line of crankshaft. Record readings. Next, measure each bore so gauge reading coincides with centerline “B” of crankshaft. Record that reading. The difference between **“A”** and **“B”** is the out-of-round condition at top of cylinder bore. Repeat the same procedure at bottom of ring travel to check for out-of-round condition. (See **SPECIFICATIONS**).



5. With reading recorded in step 4, determine taper of bore by determining the difference between “A” diameters measured at **“top”** and **“bottom”** of bore. (See **SPECIFICATIONS**)



Checking Cylinder Bore Taper

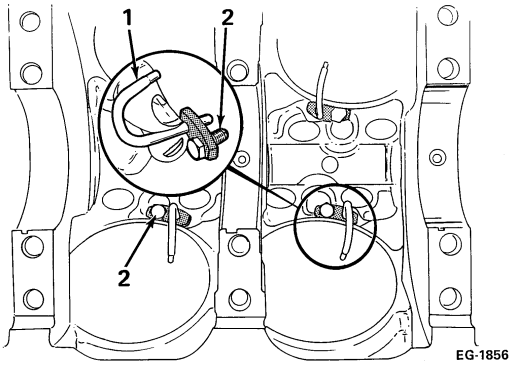
6. If cylinder bore is within specifications, standard size pistons and rings may be used.

NOTE: *Rebore cylinders that are deeply scored and/or when out-of-round and/or taper exceeds specifications.*

If cylinder walls have minor surface damage, but are otherwise within specification (out-of-round and taper), it may be possible to remove such damage by honing.

If cylinder bore is suitable for use without reconditioning, deglaze bore using glaze breaker brush then reassemble.

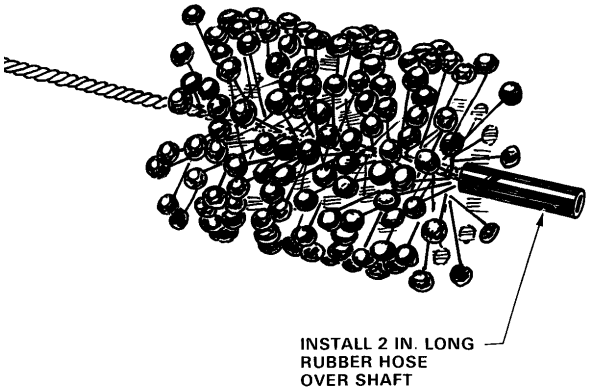
IMPORTANT: If cylinder bores are to be deglazed, piston cooling jet tubes must be removed.



1- Piston Cooling Jet
2- Piston Cooling Jet Mounting Bolt (8)

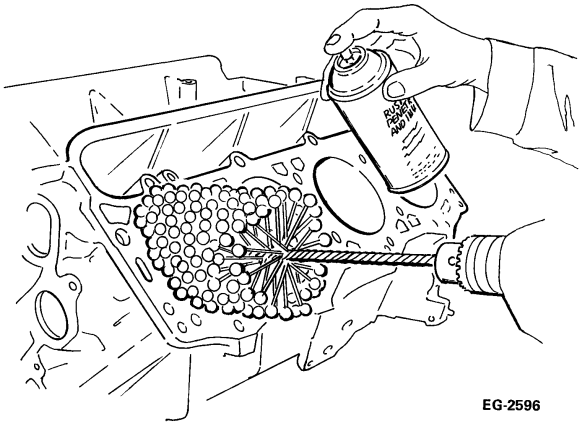
DEGLAZING

7. Cylinder bore can be deglazed using a 120 grit glaze breaker brush such as ZTSE-4349.

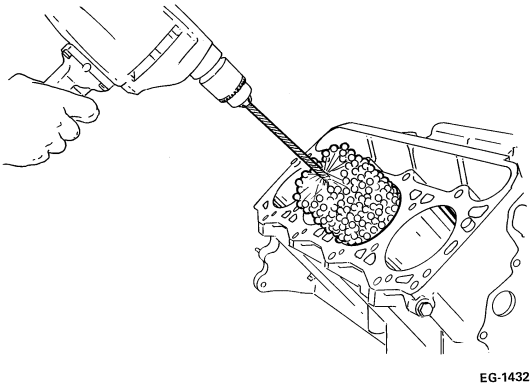


This Silicone carbide-tipped nylon flexible brush quickly deglazes cylinder walls and produces a crosshatch pattern on cylinder wall surface in a single operation. The brush contours itself to the cylinder wall and conditions wall surface without altering cylinder bore.

8. Obtain a 12 oz. can of PE-12 “Solvent and Penetrating Fluid” manufactured by AGS, available at any well-stocked auto supply house. This spray contains colloidal graphite and works well for this application. Spray both cylinder to be deglazed and flex hone.



9. Deglaze cylinder as follows:

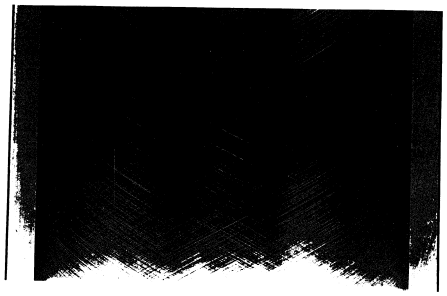


   a. Attach flex hone to an electric or air powered drill **WITH ADJUSTABLE SPEED.**

IMPORTANT: A speed of approximately 100-120 rpm is required. speed adjustment is required for procedure to be successful.

   b. Hone cylinder wall for about 15 seconds while stroking up and down at a rate of one complete up and down stroke per second.

c. Withdraw flex hone from cylinder bore while hone is rotating. Wipe a portion of the cylinder wall and visually inspect crosshatch pattern comparing it to an untouched cylinder bore.



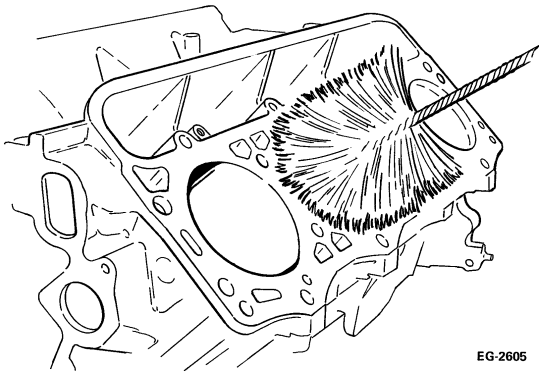
NOTE: *The crosshatch pattern should be approximately 45°.*

d. If pattern is “flatter” than required increase the up and down stroke speed or slow down the drill rotation.

e. Continue deglazing cylinder bore for 10-15 seconds or 20-25 strokes.

f. Wipe cylinder bore clean and visually inspect bore for proper 45° cross-hatch pattern.

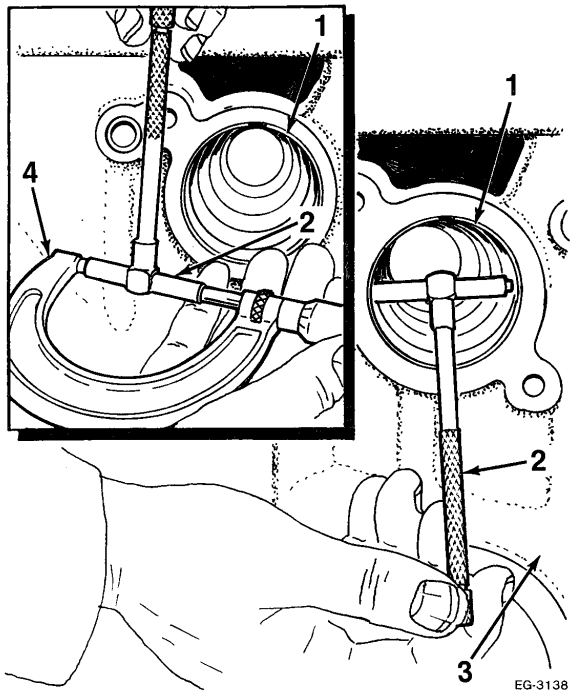
10. After deglazing, thoroughly clean cylinder bores using a soft bristle brush, soap and water. Dry with filtered compressed air and oil bore using clean engine oil.



Camshaft Bushing Inspection

Camshaft Bushing Inspection

1. Inspect the five camshaft bushings for wear and proper running clearance (see **SPECIFICATIONS**). If limits are exceeded, replace with new bushings using camshaft bushing remover and installer set **ZTSE-2393C**.



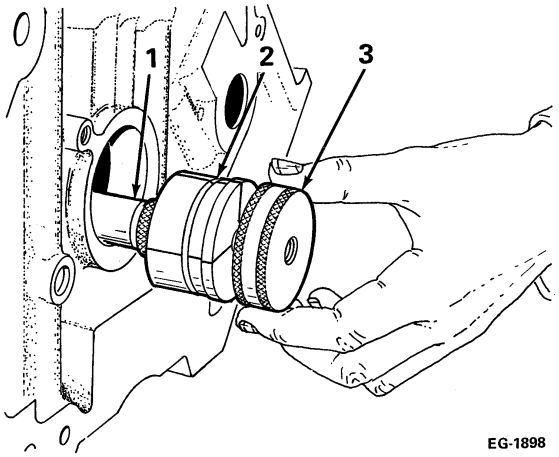
1- Camshaft Bushing
2- Telescoping Gauge
3- Crankcase
4- Micrometer

BUSHING REMOVAL

The bushings are interchangeable from one bore to another except for the front bushing which is wider than the others.

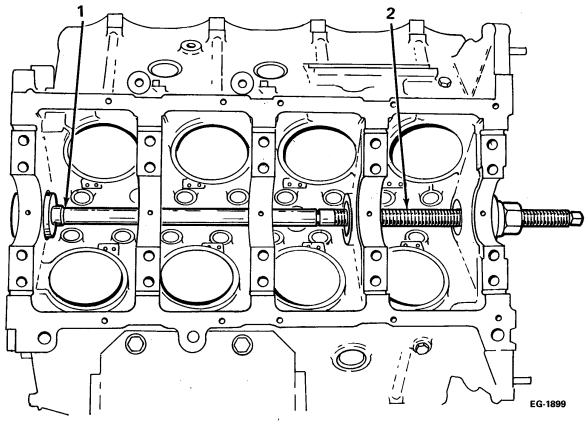
Bearing Position	Bearing Width
Front (#1)	.780”
Intermediates & Rear (#2-5)	.645”

1. Using Tool **ZTSE-2393C**, select proper size expanding collet and back-up nut and assemble onto expanding mandrel. With expanding collet collapsed, install collet assembly into camshaft bushing, and tighten back-up nut on expanding mandrel until collet fits camshaft bushing.



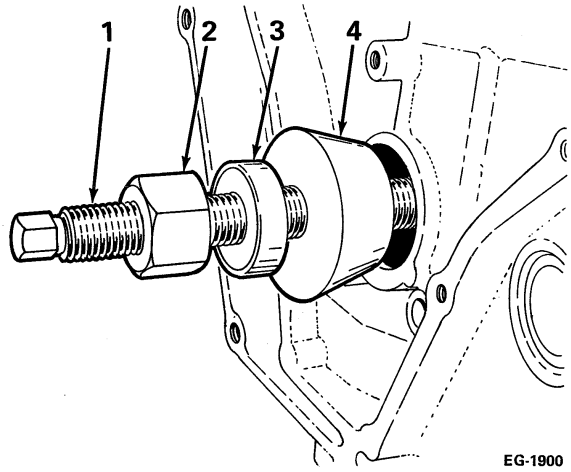
1- Pulling Screw
2- Expanding Collet
3- Back-up Nut

2. Assemble puller screw onto expanding mandrel. Wrap a cloth around threads of puller screw to protect front camshaft bushing.



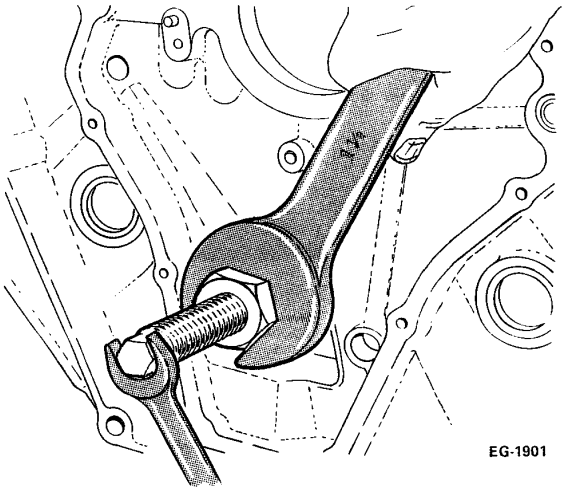
1- Expanding Mandrel
2- Puller Screw

3. Attach pulling plate thrust bearing and nut to puller screw. Tighten pulling nut against thrust bearing and pulling plate to remove camshaft bushing.



1- Puller Screw
2- Back-up Nut
3- Thrust Bearing
4- Pulling Plate

IMPORTANT: Be sure to hold a wrench on the end of the puller screw to prevent it from turning.



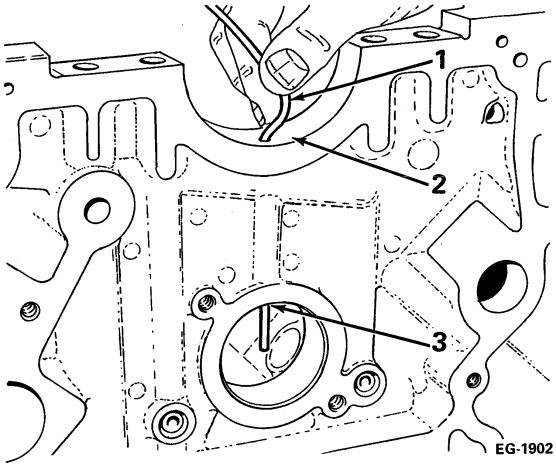
Camshaft Assembly

Bushing Installation

1. Lubricate the new camshaft bushings and bores with clean engine oil.
2. Use Tool **ZTSE-2393C** to pull in the new bushings. Be sure to center the pulling plate and puller screw to avoid bushing damage.

IMPORTANT: Failure to use the correct expanding collet can cause severe bushing damage.

IMPORTANT: All camshaft bushing oil holes must be in alignment with holes in the crankcase. Use a wire to verify oil hole alignment.

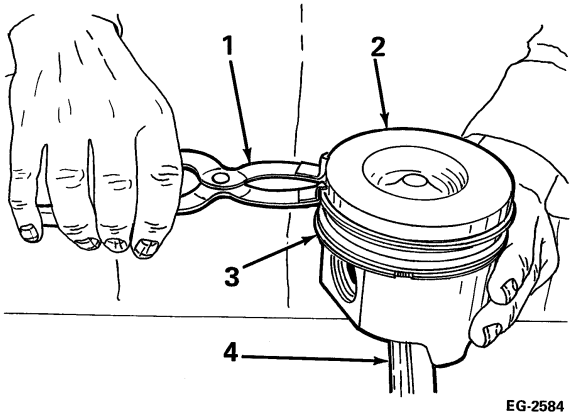


1- Alignment Wire
2- Main Bearing Saddle
3- Camshaft Bushing Oil Hole

Connecting Rods, Pistons And Rings

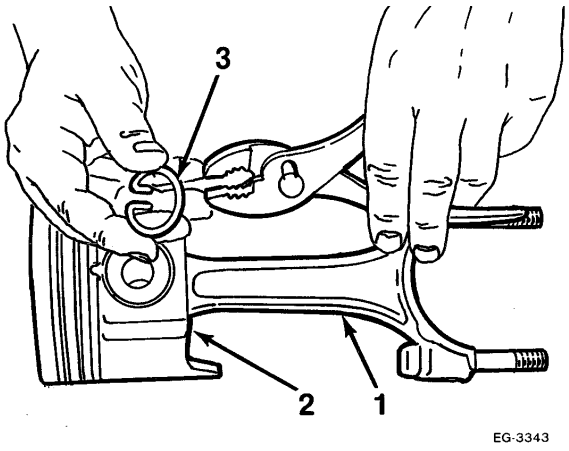
Piston Disassembly

1. Remove piston rings using piston ring expander.



1- Piston Ring Expander Tool
2- Piston
3- Piston Ring
4- Connecting Rod

2. Disconnect connecting rod from piston assembly as follows:
   a. Remove piston pin retaining rings from each end of pin.



1- Connecting Rod
2- Piston
3- Retaining Ring

NOTE: *The retaining ring has a smooth finish side and a rough finish side. The smooth finish side faces the piston pin.*

3. Separate connecting rod from piston.

IMPORTANT: Make sure parts are marked so they are reinstalled in their original locations.

Cleaning

1. Soak aluminum piston in a soap and water solution, then scrub, using a non-metallic brush.

NOTE: *Never use a caustic solution or a wire brush for cleaning aluminum pistons. Never use bead blaster on pistons.*

2. Assure all piston ring grooves are cleaned thoroughly.

Inspection

PISTONS

1. Visually inspect pistons for scuffed or scored skirts, cracked or worn ring lands and cracked or scuffed pin bores, discarding any showing such condition.
2. Piston pins should be inspected and measured for wear. If piston pins show signs of corrosion or etching or are not within specifications, they should be replaced with new pins. See **"SPECIFICATIONS"**. Piston assemblies furnished for service replacement are complete with piston pins.

Cleaning

CRANKSHAFT AND MAIN BEARINGS

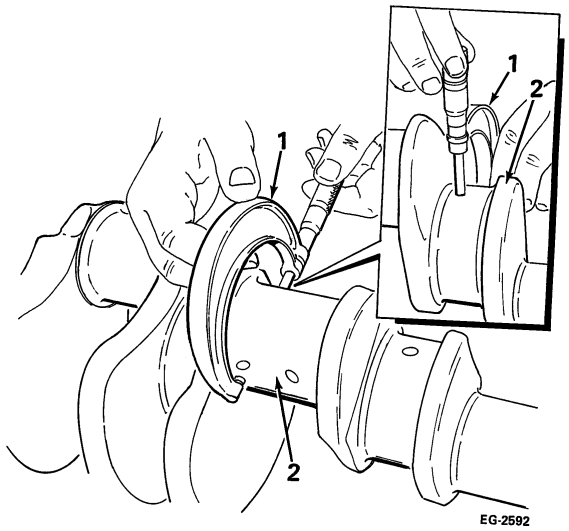
1. Clean crankshaft with a suitable solvent and dry with compressed air.
2. Clean all the internal oil passages of the crankshaft using a stiff nylon brush. Loosen all dirt, sludge and deposits which may have accumulated. Flush the oil passages with a suitable solvent.
3. Clean the bearing caps thoroughly in solvent and dry with compressed air.

Inspection and Repair

CRANKSHAFT AND MAIN BEARINGS

1. Visually inspect main bearing and connecting rod journals.
2. Measure diameter of each journal using a micrometer (see **SPECIFICATIONS**). Measure each journal at two points, at right angles to each other. Move micrometer over width of journal. Check for out-of-round and taper, (see **SPECIFICATIONS**).

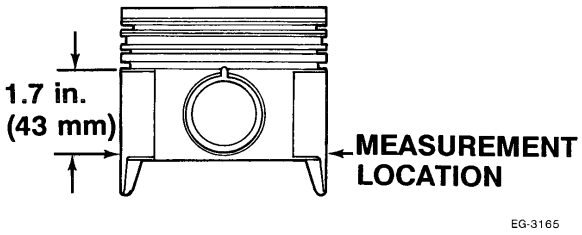
NOTE: *If journals exceed the maximum out-of-round and/or taper specifications, crankshaft must be reground or replaced.*



1- Micrometer
2- Crankshaft

PISTON SELECTION GUIDELINES

1. When pistons require replacement select as follows:
   a. If cylinder bores exceed out-of-round and/or taper specifications reboring may be required. Such cylinder bore reconditioning will require use of oversize service pistons. In addition to standard size service piston .010", .020" and .030" oversize pistons are available. Verify piston size by measuring skirt diameter.



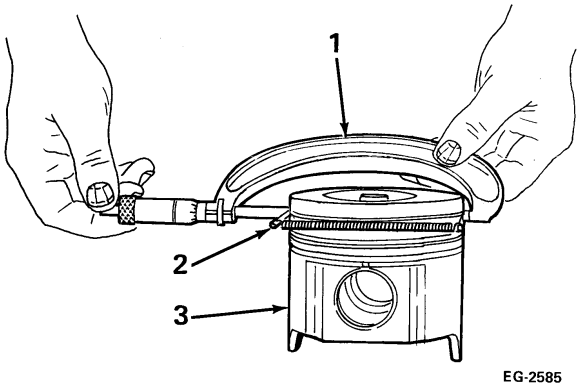
2. Check top compression ring groove for wear as follows:

IMPORTANT: Top compression ring groove is a keystone design, which requires measurement over gauge pins to determine groove wear.

a. Install the 0.1150 in. gauge pins from piston groove wear gauge pin set **ZTSE-30201**, into groove to be measured.

IMPORTANT: Gauge pins must be parallel.

b. Measure piston diameter over gauge pins using an outside micrometer.



1- Micrometer
2- Gauge Pins
3- Piston

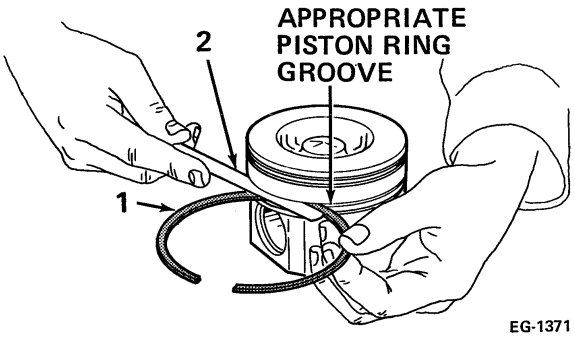
c. If measurement over gauge pins is NOT within specifications, excessive piston groove wear exists. Replace with new piston. Refer to **"SPECIFICATIONS"**.

Inspection

PISTON RINGS

NOTE: *Piston rings are available for service in standard sizes as well as .010", .020" and .030" oversize piston rings. Each ring should be fitted and checked in the cylinder in which it is to be used. Mark accordingly so they are installed in their respective bores.*

1. Check side clearance of intermediate and oil control piston rings in groove of piston on which they are to be installed, as follows:



1- Piston Ring
2- Feeler Gauge

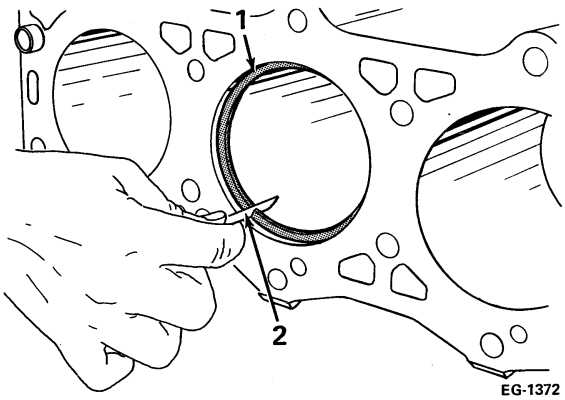
a. Place outer edge of new ring in piston groove

b. Roll new ring, in its respective groove, entirely around piston. Make sure new ring is "free" in groove.

c. With a feeler gauge check side clearance of each new ring in its respective groove. (See **SPECIFICATIONS**)

2. Visually inspect **NEW** rings for cleanliness.
3. Prior to installing rings on piston, check each ring for proper gap as follows:

a. Push ring down into cylinder bore making sure ring is square with cylinder wall. A piston head can be used as a tool for this purpose**.**



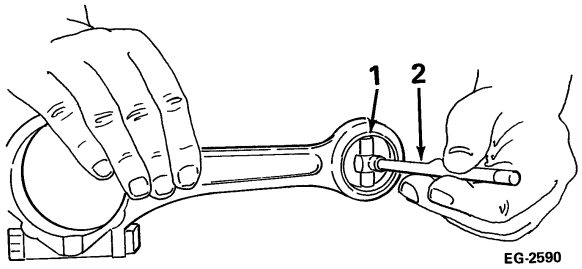
1- Piston Ring
2- Feeler Gauge

b. Measure gap between ends of each ring with a feeler gauge.

c. If gap does not meet the **SPECIFICATIONS**, select another ring or recheck cylinder bore wear.

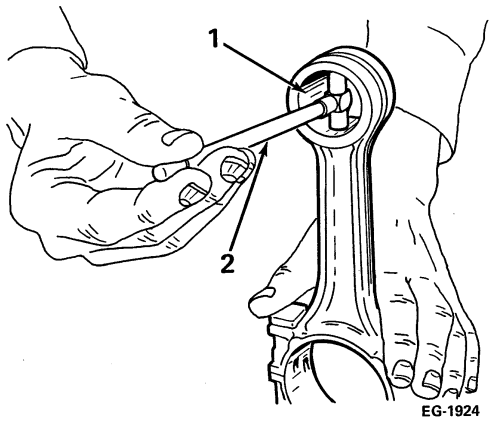
Connecting Rods

1. Visually inspect the surface finish of the connecting rod bearing bore. The bore must be smooth and free of scoring or nicks. Replace as required.
2. Measure inside diameter of piston pin bushing in connecting rod using a telescoping gauge and a micrometer. (See **SPECIFICATIONS**) If bushing is worn, replace the connecting rod.



1- Piston Pin Bushing
2- Telescoping Gauge

3. Clean connecting rod thoroughly and visually inspect for defects. Using telescoping gauge and a micrometer, check connecting rod piston pin bushing bore diameter. (See **SPECIFICATIONS**) Replace connecting rod if not within specifications.

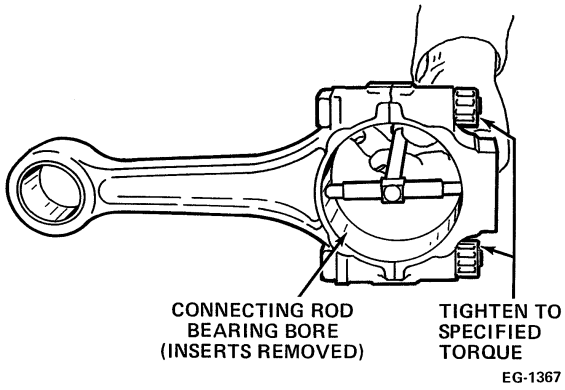


1- Piston Pin Bushing Bore
2- Telescoping Gauge

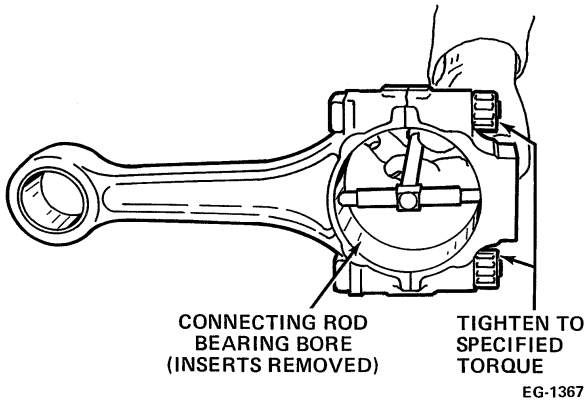
4. Continue connecting rod inspection (crankshaft end) as follows:

NOTE: *Measure connecting rod bore diameter, out-of-round and taper with connecting rod nuts tightened to special torque value. Replace connecting rod if not within specifications.*

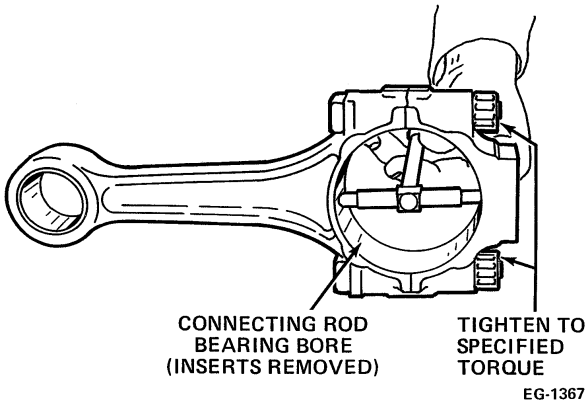
a. Measure connecting rod bearing bore diameter at three locations, 120° apart (with bearing inserts removed). (See **SPECIFICATIONS**) for bearing bore I.D.



b. Use a telescoping gauge to measure out-of-round. (See **SPECIFICATIONS**). Replace rod if maximum out-of-round specification is exceeded.



c. Measure connecting rod bore taper by measuring the bore I.D. near the large chamfer, record reading and measure the bore I.D. near the small chamfer, record reading. The difference between the two readings is the bore taper. (See **SPECIFICATIONS**) Replace rod if maximum bore taper is exceeded.



Connecting Rod Bend And Twist

1. An engine component wear pattern can be identified and used to diagnose a problem. Common examples of connecting rod wear pattern diagnostic clues are presented as follows:

   A shiny surface on edge of piston pin bushing usually indicates that a connecting rod is bent or piston pin hole is not in proper relation to a piston skirt and ring grooves.

   Abnormal connecting rod bearing wear can be caused by either a bent connecting rod, an improperly machined journal, or a tapered connecting rod bore.

   Twisted connecting rods will not create an easily identifiable wear pattern, but badly twisted rods will disturb action of entire piston, rings, and connecting rod assembly and may be the cause of excessive oil consumption.

IMPORTANT: If connecting rods do not meet requirements set forth in para- graphs 1-6 “connecting rod inspection”, replace entire con- necing rod assembly.

Assembly

BEARING FITTING PROCEDURE

1. If bearing-to-crankshaft running clearances exceed specifications, because of wear, regrind crankshaft and install undersize bearing shells.

IMPORTANT: Do not attempt to reduce journal-to-bearing running clearances by reworking bearing cap, bearings or both. Grind crankshaft only.

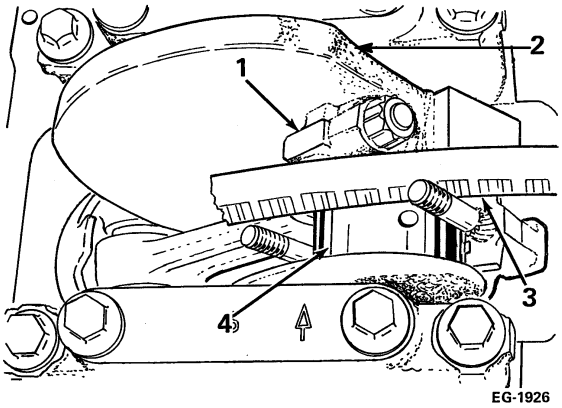
⚠CAUTION

REWORKING BEARING CAP AND/OR BEARINGS WILL DESTROY ENGINEERED FIT OF BEARING SHELLS IN THEIR BORES (BEARING CRUSH).

2. Tighten connecting rod bolts and nuts alternately and evenly to specified torque, using an accurate torque wrench. (See **SPECIAL TORQUE VALUES.**)
3. Fit connecting rod bearings and measure bearing running clearance as follows:
   a. With bearing cap removed, wipe oil from face of bearing insert and exposed portion of crankshaft journal.
   b. Place a piece of “Plastigage” across width of bearing about 1/4 in. (6.4 mm) off center.
   c. Install cap and tighten bolts and nuts evenly and alternately to specified torque.

NOTE: *Do not turn crankshaft while performing running clearance check.*

   d. Remove bearing cap. The “Plastigage” material will be found adhering to either the bearing shell or the crankshaft. **DO NOT REMOVE “PLASTIGAGE”.** Use “Plastigage®” scale to measure widest point of flattened plastic material. The number within the graduated marks on the scale indicates the clearance in thousandths of an inch and millimeters (see **SPECIFICATIONS**).



1- Connecting Rod
2- Crankshaft
3- Plastigage
4- Crankshaft Bearing Journal

   e. Remove test material and repeat test for each connecting rod bearing.

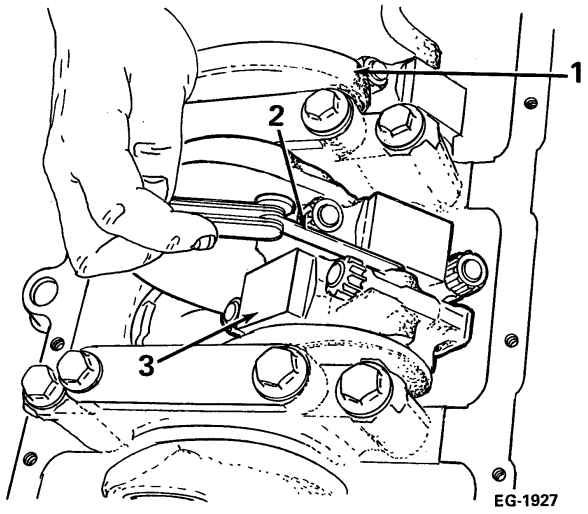
NOTE: *With precision bearings used, no problem should be encountered. However, if proper clearance is NOT achieved, a problem with the crankshaft may exist which requires regrinding and use of undersize bearings. (Refer to this section for Crankshaft Rework Information.) Additionally, bearing cap torque is very important. Use a torque wrench which is known to be accurate. Repeat running clearance check procedure before condemning crankshaft.*

4. Check connecting rod side clearance, using a feeler gauge. (See **SPECIFICATIONS**.)

NOTE: *Connecting rod end clearance must be checked to be certain that specified clearance exists.*

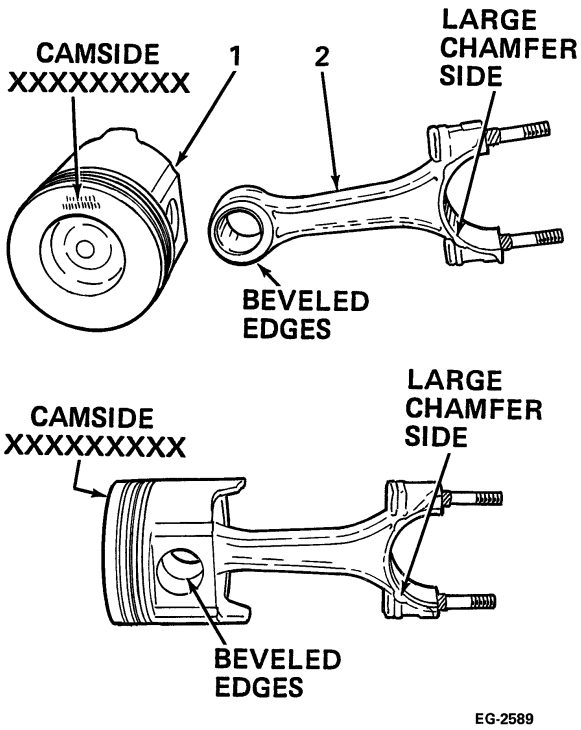
Lack of clearance could indicate a damaged rod or a rod bearing out of position. Correct as required.

Excessive clearance may require replacement of rods or crankshaft. Correct as required.



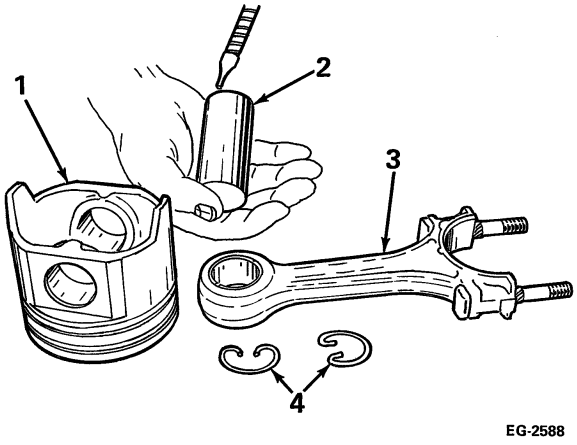
1- Crankshaft
2- Feeler Gauge
3- Connecting Rod Bearing Cap

IMPORTANT: Be sure the connecting rod and piston are assembled correctly or engine damage will occur. The large chamfer side of the connecting rod must be located next to the crankshaft fillet.



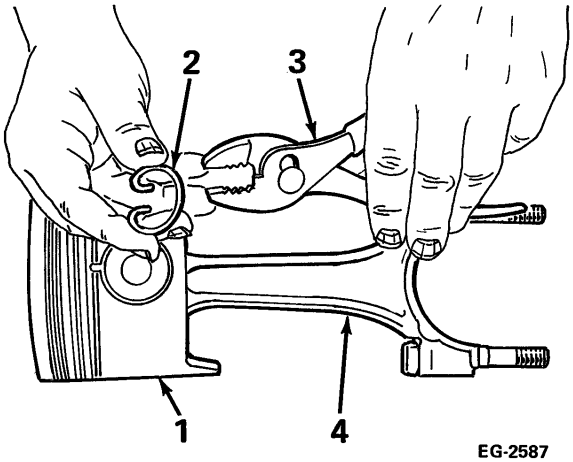
1- Piston
2- Connecting Rod

1. Lubricate piston pin with clean engine oil. Align rod bore and piston bore and insert piston pin**.**



1- Piston
2- Piston Pin
3- Connecting Rod
4- Retainer ring

2. Install piston pin and retainer snap rings. Make sure retainers seat fully with tension in the grooves.

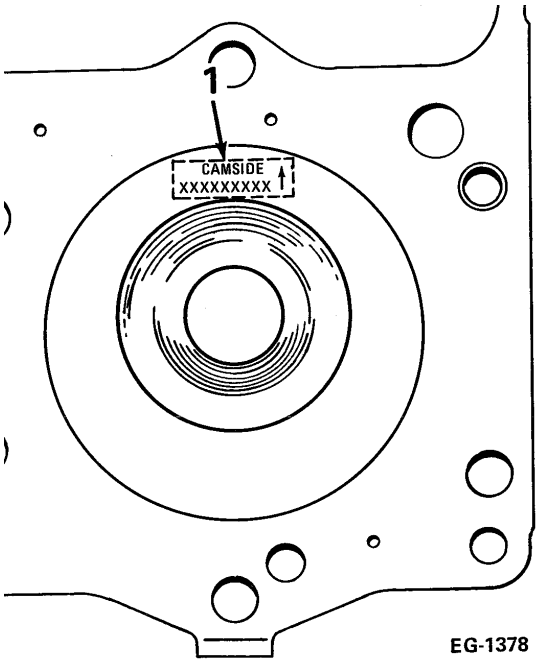


EG-2587

1- Piston
2- Retaining Ring
3- Pliers
4- Connecting Rod

PISTONS

1. The piston is best identified by the production part number which appears on top of the piston.

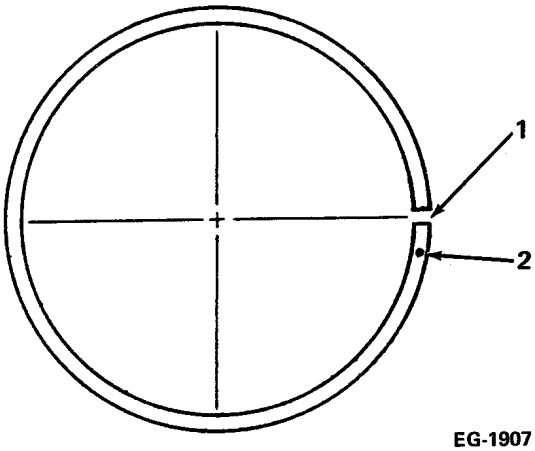


EG-1378

1- Part Number Designation At This Location.

RINGS

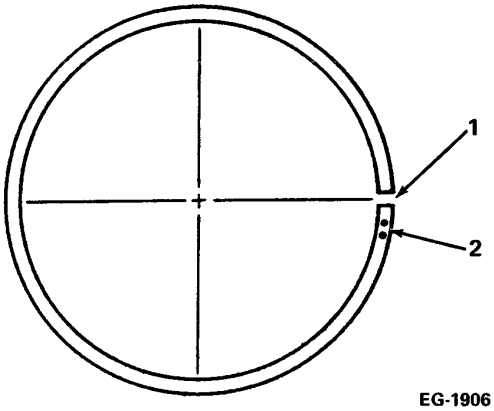
1. The top compression ring is identified by one indentation mark located on top of the ring.



EG-1907

1- Gap
2- Identification Mark

2. The intermediate compression ring is identified by two indentation marks located on top of the ring.

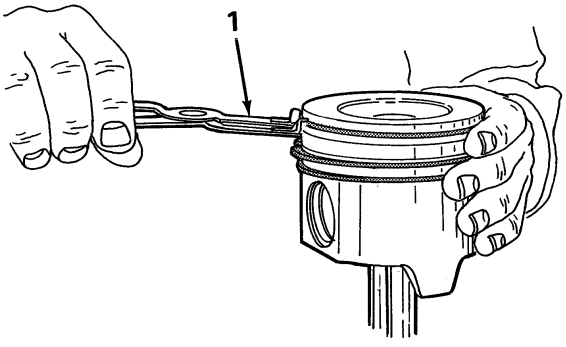


EG-1906

1- Gap
2- Identification Mark

IMPORTANT: Install in order:
1 - Oil Control Ring
2 - 2nd Compression Ring
3 - Top Compression Ring
Space ring gaps 120 degrees apart.

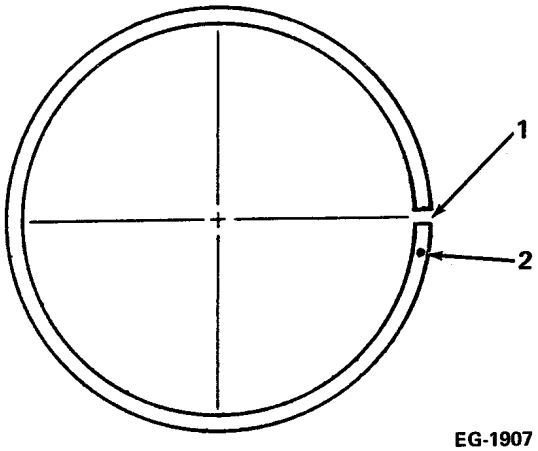
3. Assemble the rings on the pistons to which they were fitted by using a piston ring expander tool.



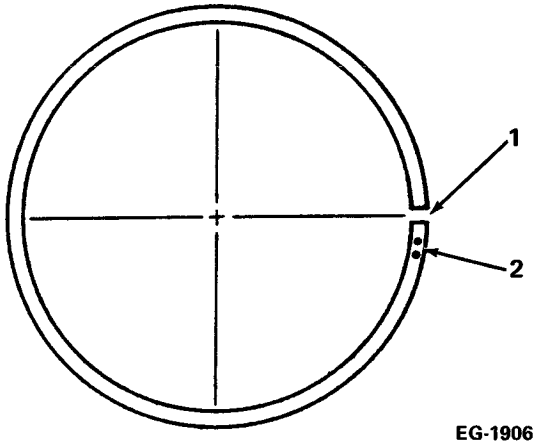
EG-1383

1- Piston Ring Expander Tool

a. Install rings with identification markings on ring facing up.



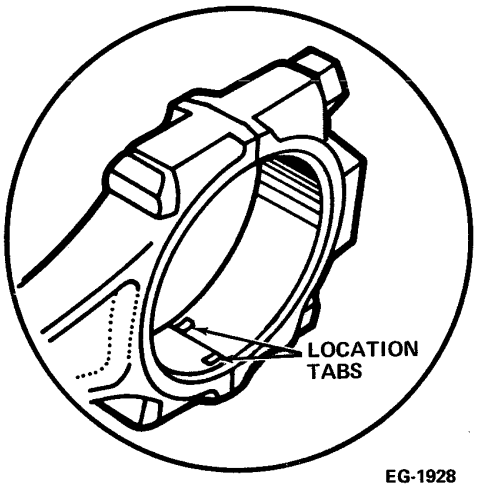
1- Gap
2- Identification Mark



1- Gap
2- Identification Mark

b. Space the ring gaps 120° apart.

4. Install bearing shell inserts chosen during bearing fitting procedure. Bearing locator tabs aid in correct insert installation.

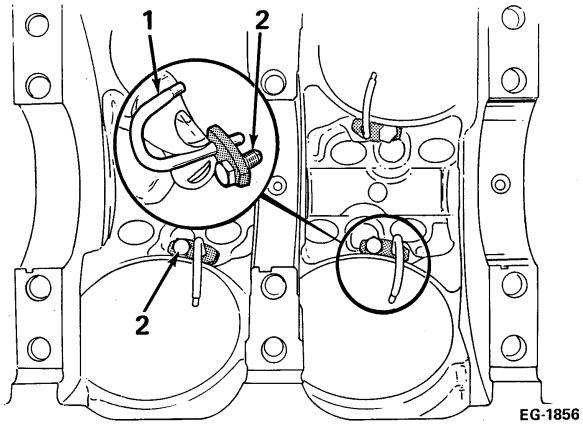


Piston Cooling Jet Tubes

Cleaning and Inspection

1. With cooling jet tubes removed, run an appropriate size wire through tube to assure there is no blockage. Replace cracked or bent tubes.
2. Blow out any debris from cleaning, using filtered compressed air.

Installation



1- Piston Cooling Jet Tube
2- Patch Bolt

NOTE: *Retaining bolts are special "patch type" bolts, DO NOT substitute.*

1. Place jet tube assembly onto crankcase mounting pad.

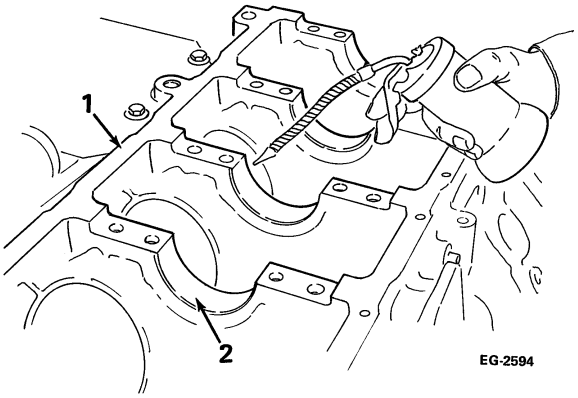
NOTE: *Bolt-on piston cooling jet tubes are self aligning.*

2. Tighten special patch bolt to standard torque.
3. Do not substitute bolts, use only specified 6.35mm -20x15mm "patch type" bolts.

Crankshaft And Main Bearings

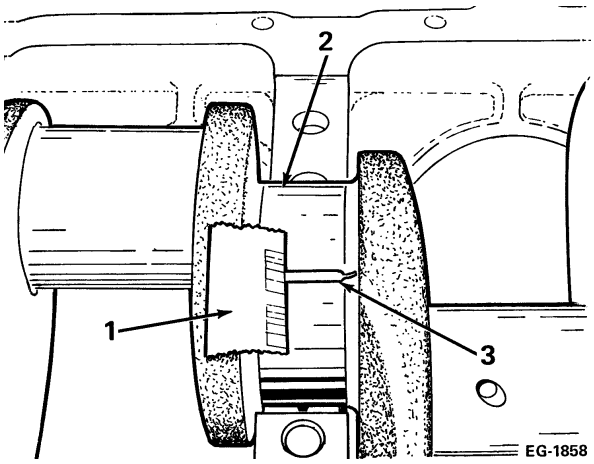
Installation

1. Using a lint-free cloth, wipe crankcase bearing supports free of oil.
2. Clean bearings inserts and caps thoroughly in solvent and dry with compressed air.
3. Visually inspect each bearing. Replace all bearings, if any, that are scored, chipped or worn.
4. Check Bearing clearance as follows:
   a. Install bearing upper halves into the crankcase. Be sure locking tabs on bearings are snapped into crankcase saddle and oil holes in bearing shells line up with oil holes in crankcase.
   b. After oiling, carefully install crankshaft into crankcase.



1- Crankcase
2- Main Bearing Insert

   c. Install lower main bearing halves with cap and tighten inner and outer bolts to specified torque.
   d. Remove one bearing cap at a time. Remaining caps are left tight while checking fit of bearing with cap removed.
   e. Wipe oil from all contact surfaces of exposed journal, bearing insert and cap.
   f. Place a piece of Plastigage across the full width of bearing surface on crankshaft journal (or bearing cap insert) approximately 1/4 in. (6.4 mm) (off center). Install bearing cap and tighten cap bolt to special torque value.
   g. Remove bearing cap and insert.
   h. Do not disturb Plastigage. Using the Plastigage paper gauge envelope, measure widest point of Plastigage. This reading indicates bearing running clearance.

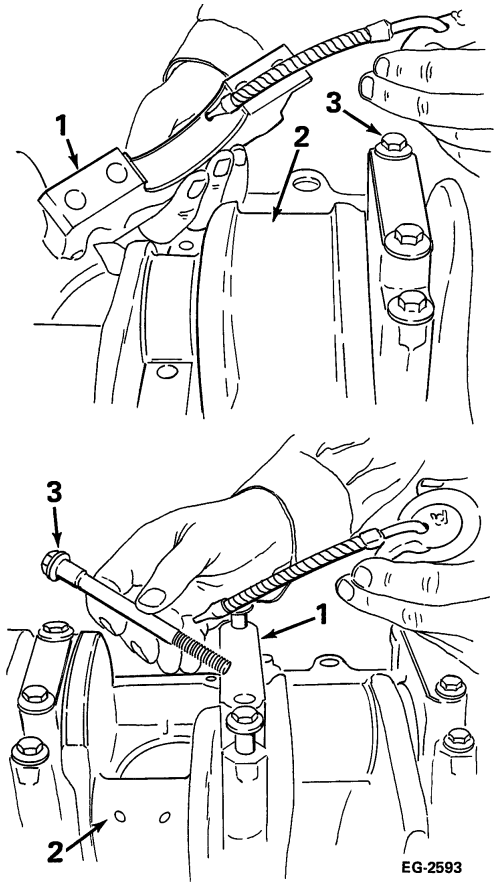


1- Paper Gauge
2- Main Bearing
3- Flattened Plastigage

   i. If bearing running clearance is not within specifications, crankshaft must be reground and undersize bearings installed.

NOTE: *When bearing clearance is checked, crankshaft will have to be supported and held against upper main bearing halves to get a correct Plastigage reading. Use a jack at counterweight next to each main bearing being checked to support crankshaft. Failure to support crankshaft will result in inaccurate readings.*

5. When acceptable bearing clearance is achieved with either old or new parts, proceed as follows:
   a. Clean Plastigage from bearing or crank- shaft journal surface.
   b. Coat all bearing surface journals and bolts with clean engine oil.
   c. Place bearing caps with bearing lower halves over crankshaft. Be sure bearing caps are properly installed. Number 1 is in the front position.

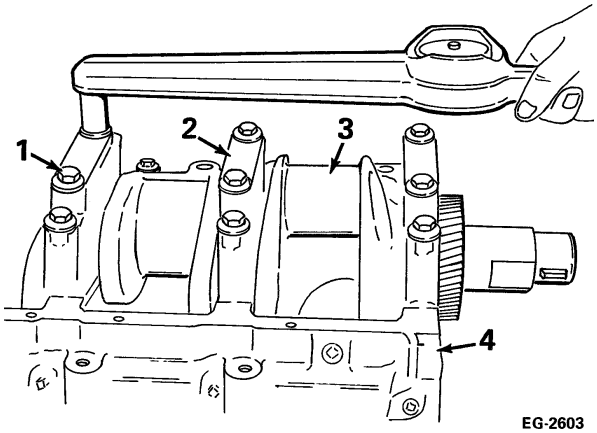


1- Main Bearing Cap
2- Crankshaft
3- Mounting Bolt (20)

IMPORTANT: Bearing caps are numbered for re-installation. do not intermix. Install bearing caps with stamped arrow facing front of engine.

d. Install main bearing caps and tighten bolts finger tight. Using a soft hammer, tap number 2, 3 and 4 bearing caps until rear machined faces of caps are flush with machined faces of crankcase.

e. Number 5 bearing rear thrust flanges must be flush with each other. Aligning caps in this manner will assure proper cap location. Check this alignment at both sides (left and right) of bearing caps. Tighten main bearing cap bolts 1 thru 4 to specified torque, leave No.5 finger-tight.



1- Mounting Bolt (20)
2- Main Bearing Cap
3- Crankshaft
4- Crankcase

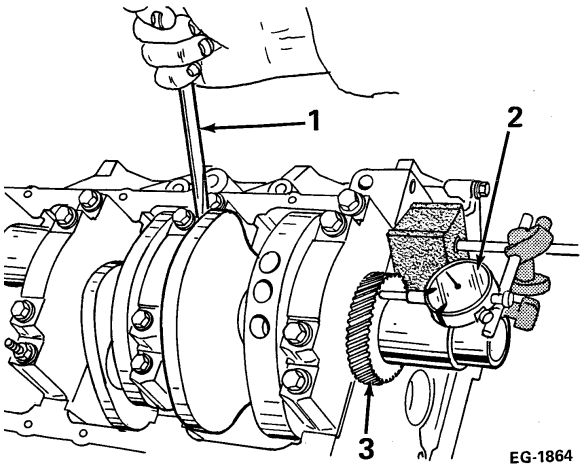
6. The thrust bearing (No. 5 Main Bearing) provides initial location of crankshaft in relation to crankcase. Check crankshaft end play using a dial indicator as follows:

   Mount dial indicator on crankcase with indicator tip on crankshaft gear.

   Torque all bearing caps (except No. 5 thrust bearing) to specified torque. Pry crankshaft forward and backward.

   Torque No. 5 thrust bearing to specified torque. Pry crankshaft forward and zero dial indicator.

   Pry crankshaft forward and zero dial indicator. Check end play by prying crankshaft back and forth while reading dial indicator.



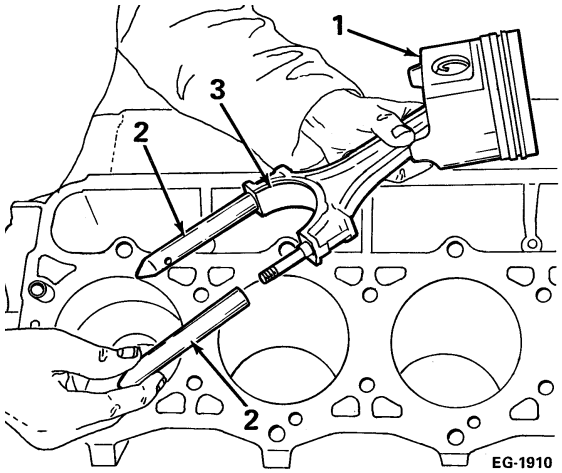
1- Pry Bar
2- Dial Indicator
3- Crankshaft Gear

If end play exceeds specification, replace thrust bearing. If end play is less than minimum limit, thrust bearing faces are damaged or dirty. If not damaged or dirty they were probably misaligned. After inspection, either clean or replace thrust bearing, align faces and parting line, following bearing installation procedure in this section. Recheck crankshaft end play.

Piston Installation

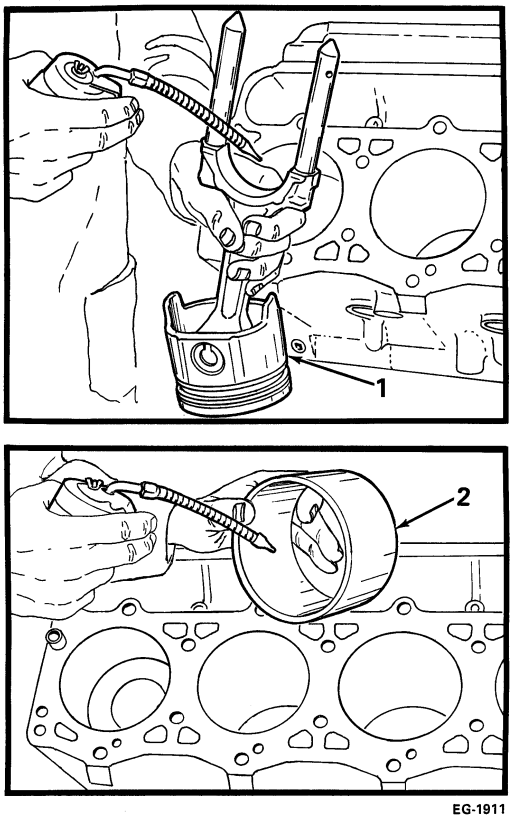
1. Turn crankshaft so the Number 1 crankpin is at the bottom of its stroke.

IMPORTANT: Before installing piston and connecting rod assembly be sure connecting rod bearing is in place. Install aluminum connecting rod protector caps (ztse-4311) onto connecting rod bolts. This prevents damage to crankshaft journals.



1- Piston And Connecting Rod Assembly
2- Protector Caps
3- Connecting Rod Bearing (16)

2. Coat cylinder bores, crankshaft journals, piston, piston rings and piston installer sleeve with clean engine oil.

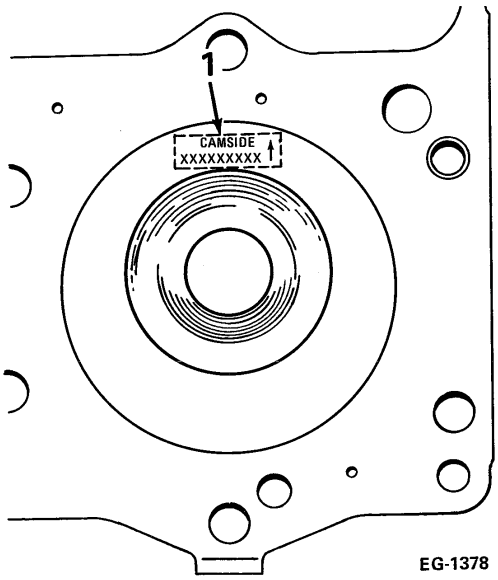


1- Piston And Connecting Rod
2- Piston Installer Sleeve

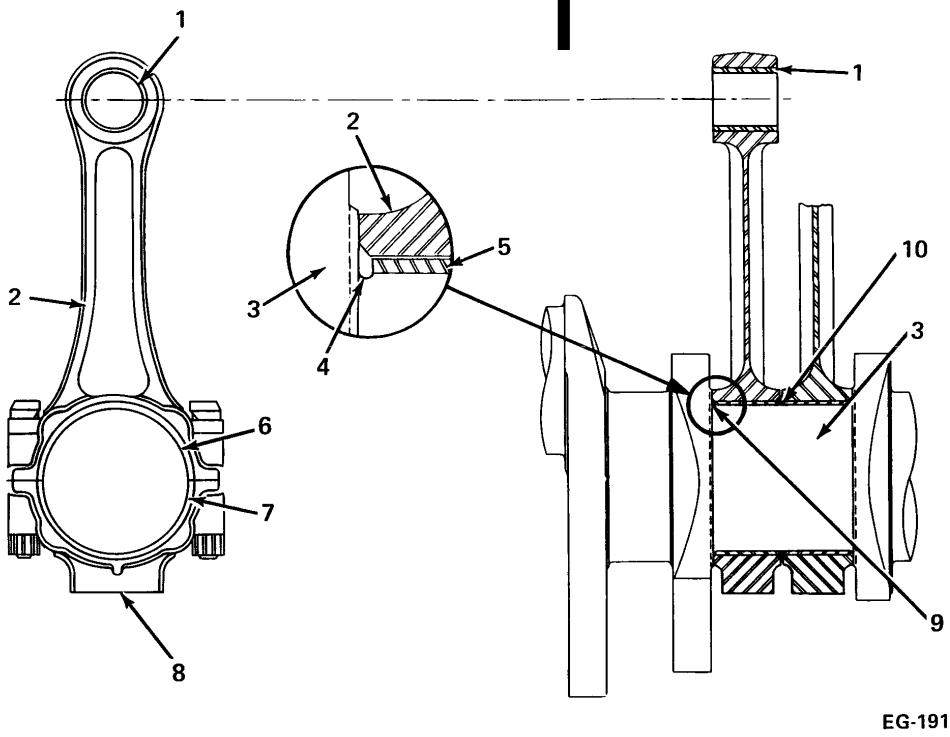
IMPORTANT: Connecting rod and piston must be positioned as follows:

Piston - arrow on top of piston must face cam side of engine block

Connecting rod - large chamfer must be located next to crankshaft fillet

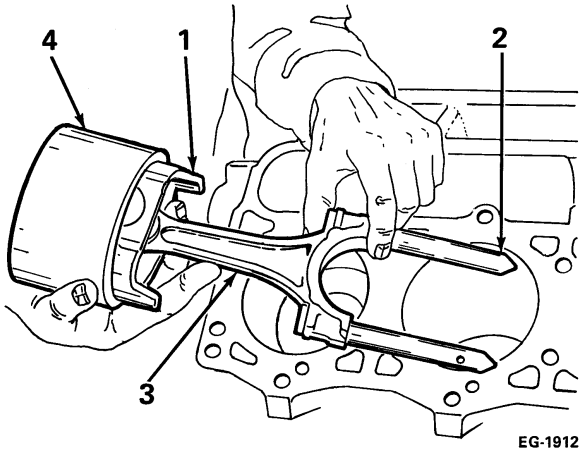


1- Identification Mark.



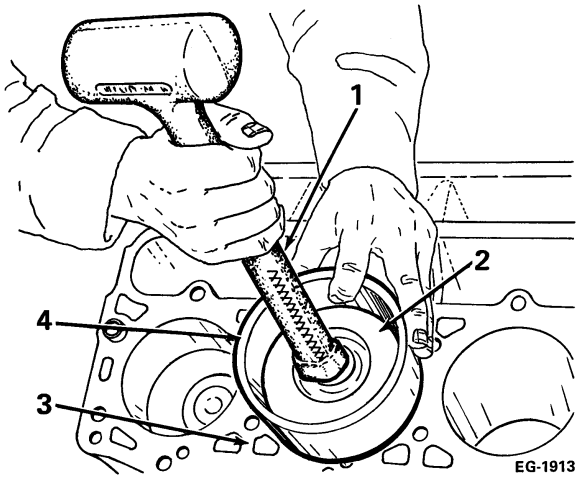
1- Piston Pin Bushing
2- Connecting Rod
3- Crankshaft
4- Crankshaft Fillet
5- Bearing
6- Connecting Rod Bearing - Upper
7- Connecting Rod Bearing - Lower
8- Connecting Rod Bearing Cap
9- Large Chamfer Side (Next to Fillet)
10- Small Chamfer Side

3. Install piston installer sleeve onto piston. Carefully place the piston and connecting rod assembly into crankcase bore.



1- Piston
2- Crankcase Bore
3- Piston And Connecting Rod Assembly
4- Piston Installer Sleeve

4. Holding the piston installer sleeve, use the handle of a hammer and tap piston into crankcase bore.



1- Hammer Handle
2- Piston
3- Crankcase
4- Piston Installer Sleeve Tool.

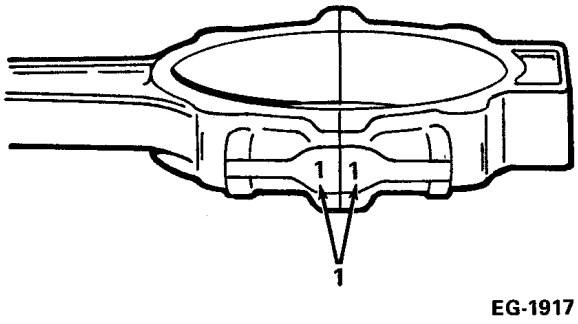
5. Remove connecting rod bolt protector caps.

NOTE: *Rods and caps are matched. Assemble connecting rod and cap with matching identification code on the same crankpin from which removed.*

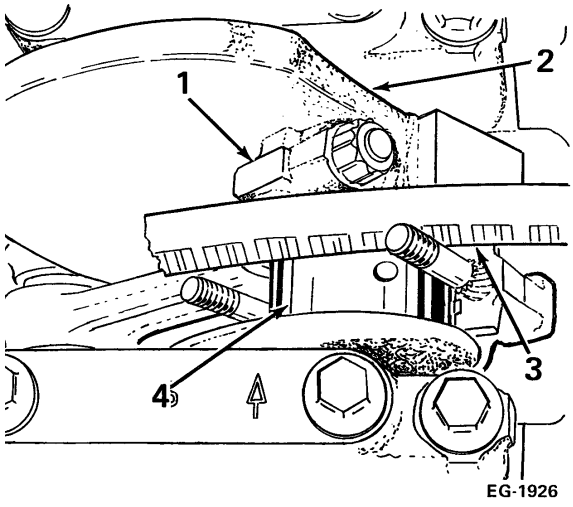
6. Check rod bearing running clearance as follows:
   a. With bearing cap removed, wipe oil from face of bearing insert and exposed portion of crankshaft journal.
   b. Place a piece of "Plastigage®" across full width of bearing about 1/4 in. (6.4 mm) off center.
   c. Install cap and tighten bolts and nuts evenly and alternately to specified torque.

NOTE: *Do not turn crankshaft while performing running clearance check.*

   d. Remove bearing cap. The "Plastigage®" material will be found adhering to either the bearing shell or the crankshaft. **DO NOT REMOVE PLASTIGAGE.** Use "Plastigage®" scale to measure widest point of flattened plastic material. The number within the graduated marks on the scale indicates the clearance in thousandths of an inch and millimeters (see **SPECIFICATIONS**).
   e. Remove test material and repeat test for each connecting rod bearing.



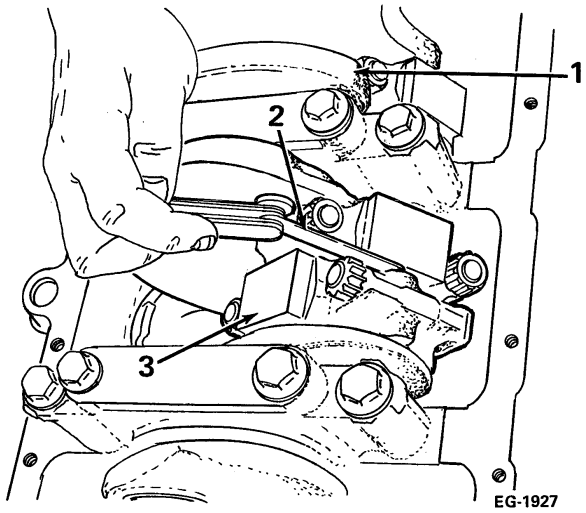
1- Connecting Rod And Cap Identification.



1- Connecting Rod
2- Crankshaft
3- Plastigage
4- Crankshaft Bearing Journal

NOTE: *With precision bearings used, no problem should be encountered. However, if proper clearance is NOT achieved, a problem with the crankshaft may exist which requires regrinding and use of undersize bearings. Additionally, bearing cap torque is very important. Use a torque wrench which is known to be accurate. Repeat running clearance check procedure before condemning crankshaft.*

7. Check connecting rod side clearance, using a feeler gauge. (See **SPECIFICATIONS**.)



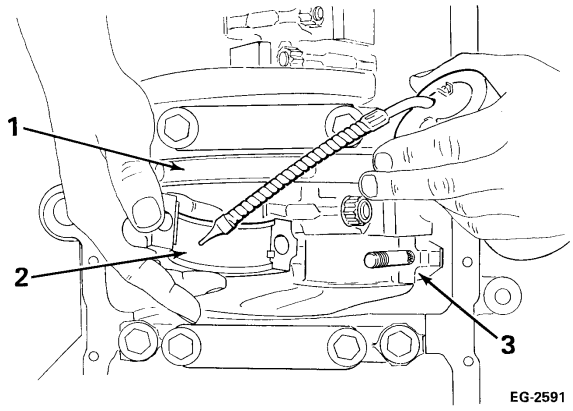
1- Crankshaft
2- Feeler Gauge
3- Connecting Rod Bearing Cap

NOTE: *Connecting rod side clearance must be checked to be certain that specified clearance exists.*

Lack of clearance could indicate a damaged rod or a rod bearing out of position. Correct as required.

Excessive clearance may require replacement of rods or crankshaft. Correct as required.

8. Coat bearing shell insert wear surface with clean engine oil and install connecting rod bearings and bearing caps.

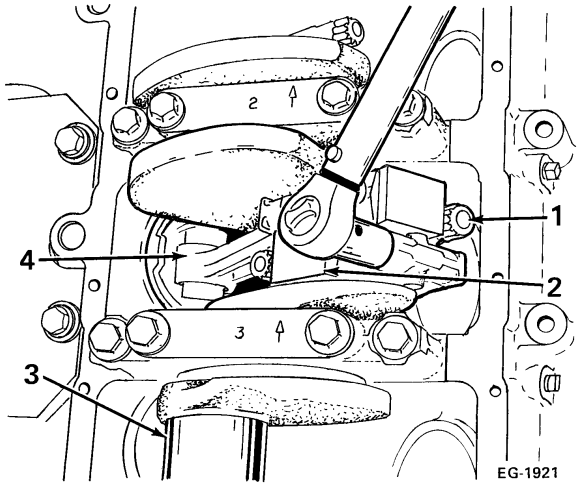


1- Crankshaft
2- Bearing Shell Insert
3- Connecting Rod

9. Apply clean engine oil to connecting rod bolt threads prior to tightening.

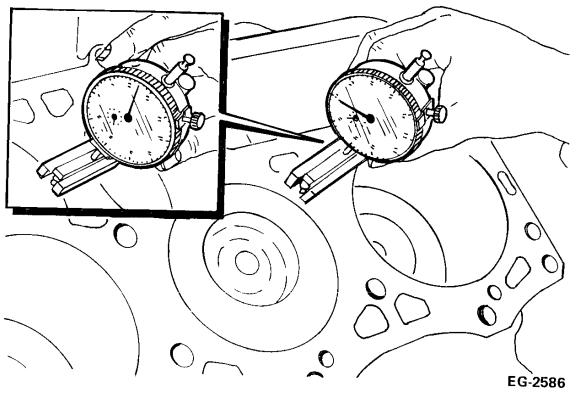
NOTE: *Do not use an air wrench when installing connecting rod bolts and nuts. Such practice may cause seizure of connecting rod bolt or nut threads.*

10. Tighten connecting rod bolts and nuts to specified torque. (See Special Torque Values).



1- Connecting Rod Nuts (16)
2- Connecting Rod Bearing Cap (6)
3- Crankshaft
4- Connecting Rod (8)

11. Check piston protrusion above crankcase as follows:
    a. Zero surface gauge on crankcase deck surface.
    b. Position dial indicator tip onto piston head.
    c. Bar crankshaft to measure the maximum piston protrusion.
    d. Record reading.

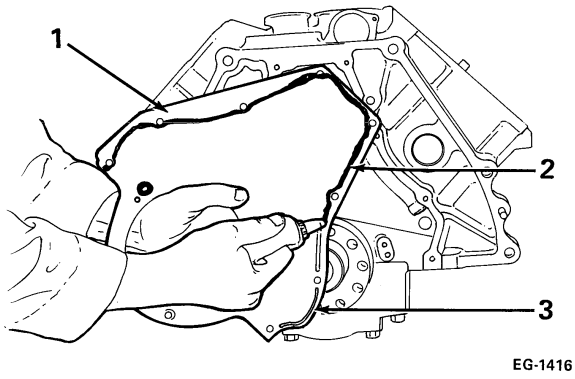


12. Repeat steps 1-11 for remaining connecting rods and pistons.

Rear Oil Seal Wear Sleeve Installation

REAR COVER INSTALLATION

1. Install rear cover as follows:
   a. Apply RTV sealant to groove in rear cover and around dowel pin holes, two (2) places.
   b. Install rear cover to crankcase. Crankcase dowels align rear cover properly. Tighten rear cover bolts to specified torque.



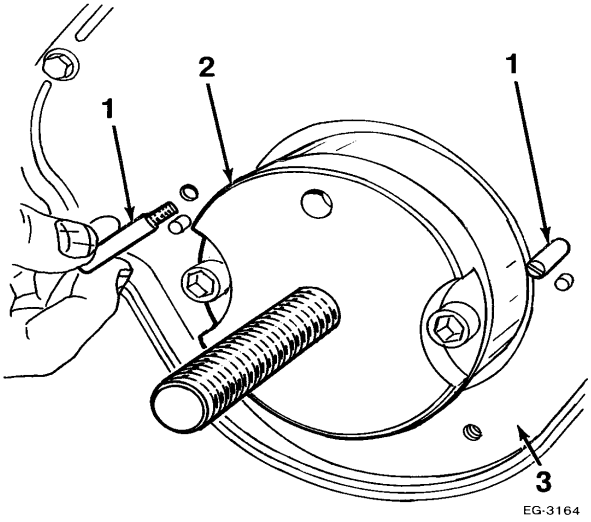
1- Rear Cover
2- RTV Sealant
3- Rear Cover Groove

NOTE: *If crankcase dowel pins are damaged or missing, replace prior to installation of rear plate. If rear cover's dowel holes are damaged or cover is bent, replace with new cover.*

Rear Oil Seal and Wear Sleeve Installation

IMPORTANT: Do not remove wear sleeve from oil seal.

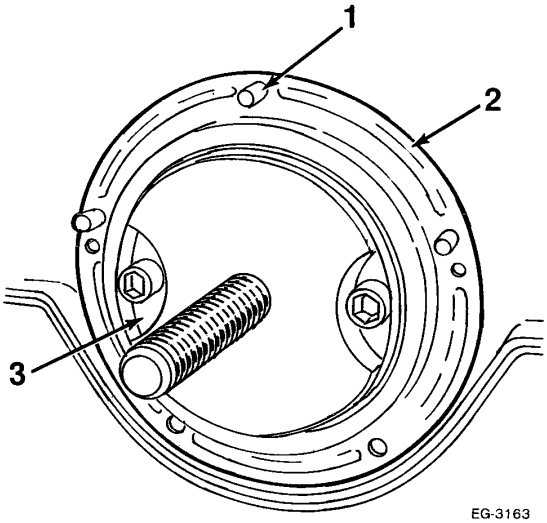
1. Install Rear Seal Installer tool (**ZTSE-4318)** onto crankshaft flange. Install two (2) rear seal alignment dowels **ZTSE43184.**



1- Alignment Dowels
2- Installer Tool
3- Rear Crankcase Cover

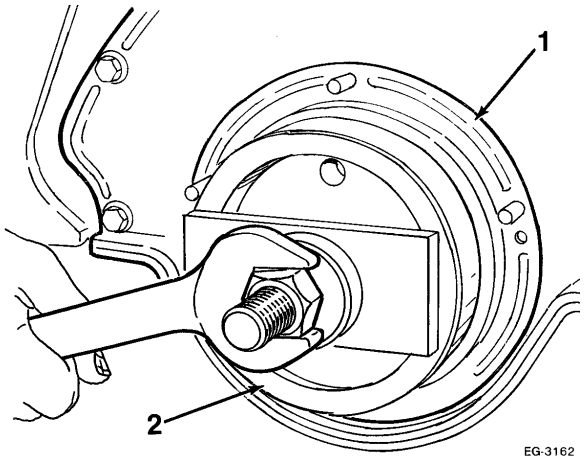
2. Apply Loctite® #515 sealant to O.D. of crankshaft flange. Also apply a bead of RTV around each bolt hole and the inside diameter of the bolt hole pattern to the seal/retainer.
3. Place seal and wear sleeve assembly over centering tool and position seal retainer over alignment dowels.

NOTE: *Be sure seal retainer and crankcase dowels align as seal is being installed.*



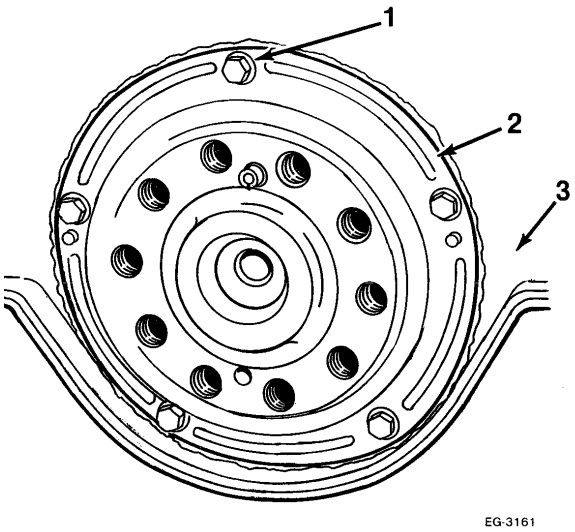
1- Alignment Dowel
2- Seal/Retainer
3- Wear Sleeve/Seal Installer Tool

4. Install driver over centering tool and tighten forcing screw driving wear sleeve and rear seal into position.



1- Seal/Retainer
2- Installation Tool

5. Apply RTV to rear oil seal retainer bolts and tighten to specified torque.



1- Rear Oil Seal Retainer Bolts (5)
2- Seal/Retainer
3- Rear Crankcase Cover

Flywheel (Reconditioning)

Cleaning

1. Clean with a non-caustic solvent, then visually inspect flywheel for cracks, heat checks and extensive scoring which would make it unfit for further service. Replace as required.

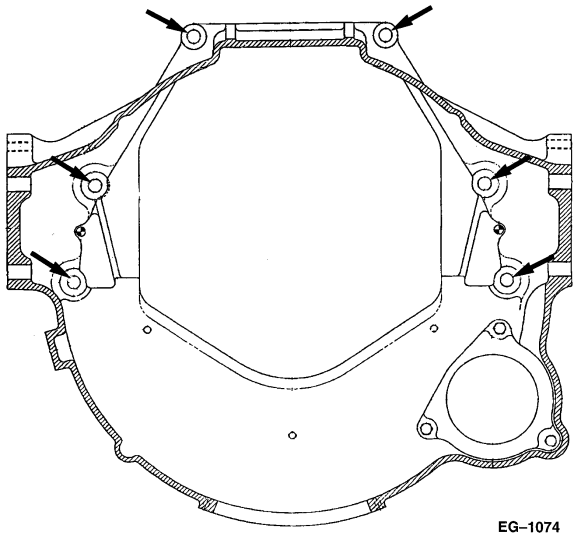
Inspection

RING GEAR REMOVAL

1. Heat ring gear with a torch on engine side of gear.
2. Once heated, knock it off flywheel. **DO NOT HIT FLYWHEEL WHEN REMOVING RING GEAR.**

RING GEAR INSTALLATION

1. If new ring gear is required, heat new ring gear evenly until gear expands enough to slip onto flywheel. Make sure gear is seated properly against shoulder. Do not heat any portion of gear to a temperature higher than 500° F (278°C). If this limit is exceeded, the hardness will be removed from ring gear teeth.
2. Install flywheel housing over dowel pins. Attach with the six flange head mounting bolts and tighten to specified torque.



3. Install flywheel and ring gear assembly as follows:
   a. Install two guide studs on crankshaft flange and slide flywheel onto guide studs.

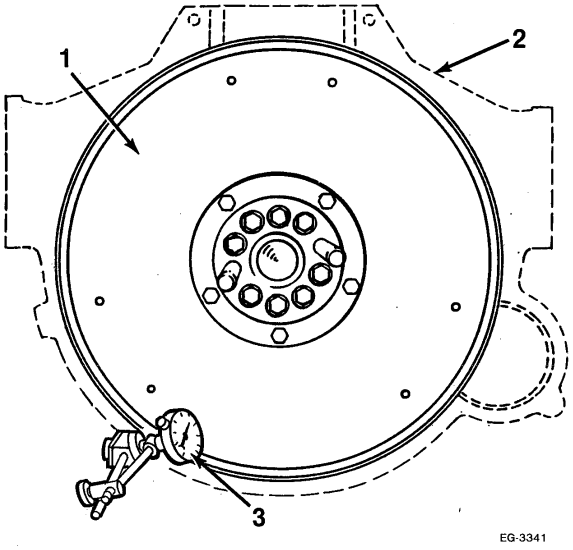
NOTE: *Be sure flywheel holes and dowel pin holes are in line with their mating bolt and dowel pin holes in the crankshaft flange.*

b. Install reinforcement ring and install seven of the nine flywheel bolts.

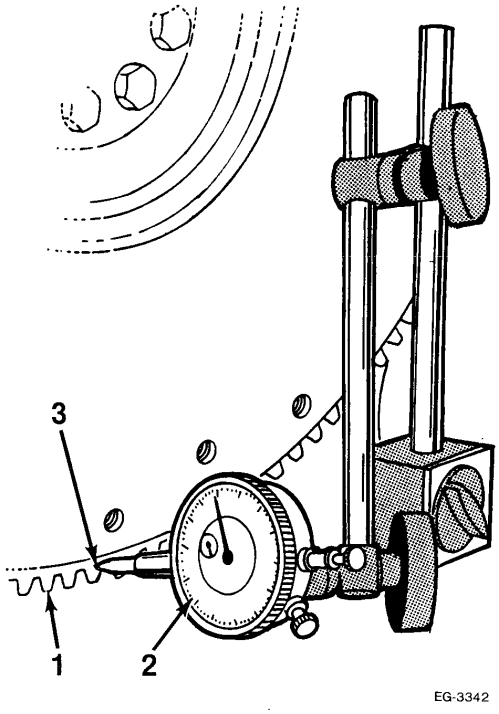
c. Tighten the seven bolts to specified torque and remove the two guide studs. Install the two remaining bolts. Tighten to specified torque .

4. With flywheel installed on crankshaft, check flywheel face and ring gear run-out as follows:

   a. For flywheel face run-out, install a dial indicator so indicator point bears against flywheel face one inch in from edge of flywheel. For checking ring gear run-out, install dial indicator point on face of ring gear adjacent to gear teeth.



1- Flywheel
2- Flywheel Adapter Housing
3- Dial Indicator



1- Ring Gear
2- Dial Indicator
3- Indicator Tip

b. Push flywheel forward prior to turning flywheel, so crankshaft “end play” will not be indicated as flywheel run-out.

c. Set dial indicator to zero. Turn flywheel one complete revolution while observing total indicator run-out (TIR).

d. If flywheel face TIR exceeds specifications, remove flywheel and check for burrs between flywheel and face of crankshaft mounting flange. Remove burrs as required.

e. If no burrs exist, check crankshaft flange runout, using a dial indicator.

   If crankshaft flange runout is within specifications, replace flywheel.

f. If ring gear TIR exceeds specifications, check ring gear installation. Reheat gear evenly until it expands enough to be properly seated on flywheel shoulder.

g. Recheck runout; if not within specifications, replace flywheel and ring gear assembly.

5. Install adapter and coupler on flywheel. Torque as follows:
   Adapter-to-Flywheel - Torque to 20 lb.ft. (27 N.m)
   Coupler-to-Adapter - Torque to 55 lb.ft. (74 N.m)

Oil Filter and Cooler

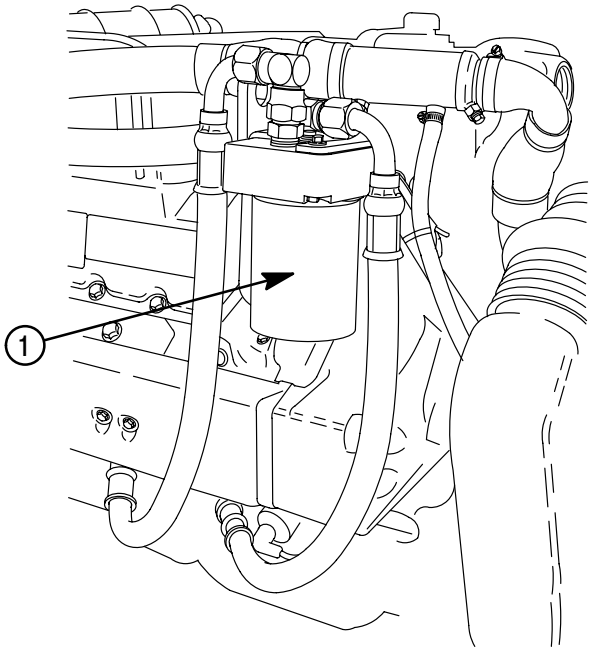
Special Torque Values

Oil Pan Drain Plug	28 lb.ft. (37 N·m)

Oil Filter

REMOVAL

1. Remove oil filter by turning counterclockwise (as viewed from bottom).
2. Ensure seal is removed from adapter.



76100

1- Oil Filter

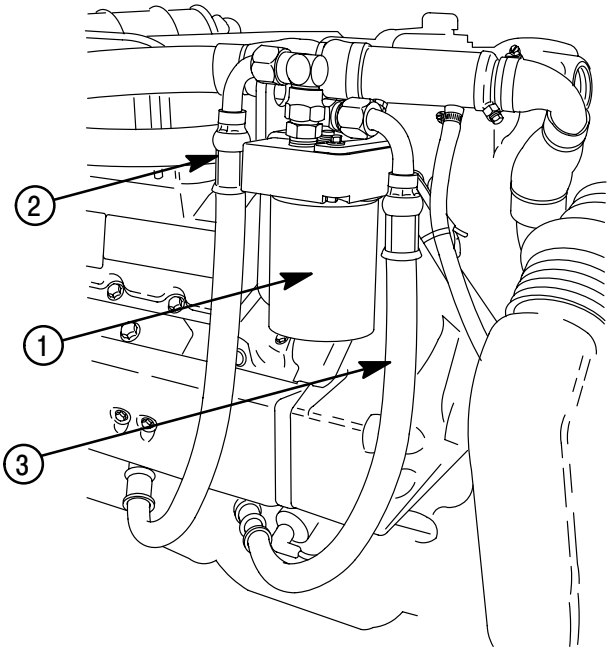
INSTALLATION

1. Lubricate seal on new filter with oil.
2. Install oil filter by turning clockwise (as viewed from bottom).
3. Tighten filter by hand. Do not use a filter wrench.

Oil Filter Adapter

REMOVAL

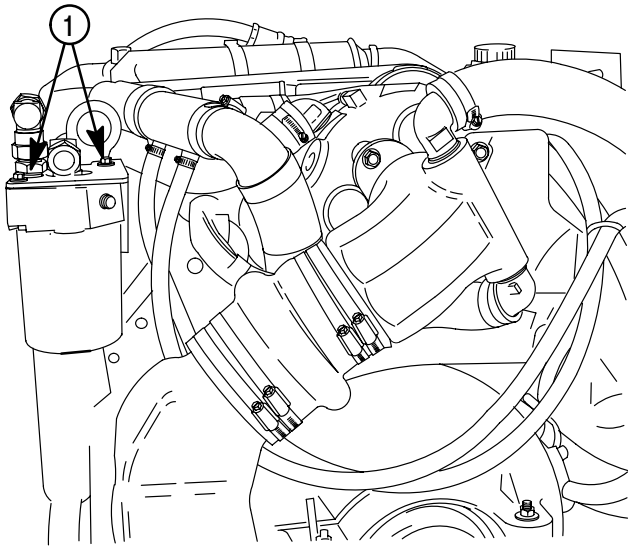
1. Remove oil filter. Refer to previous procedure.
2. Disconnect oil hoses from oil filter adapter.



76100

1- Oil Filter
2- Oil Hose To Block Adapter (Front)
3- Oil Hose To Block Adapter (Rear)

3. Remove bolts at top side of bracket. Remove adapter.



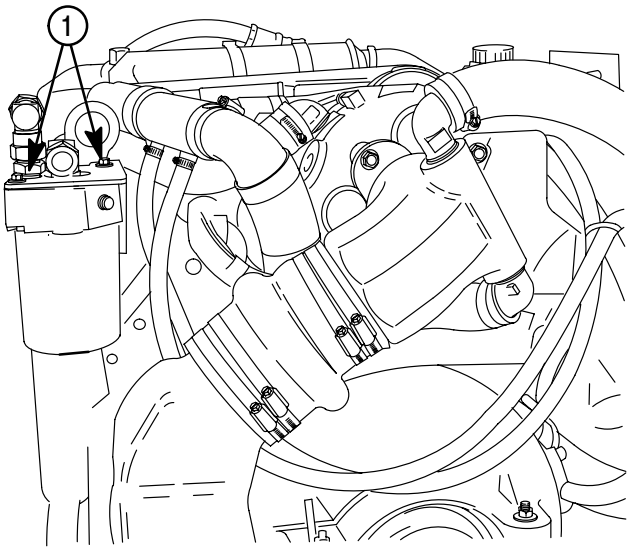
76219

.

1- Bolts

INSTALLATION

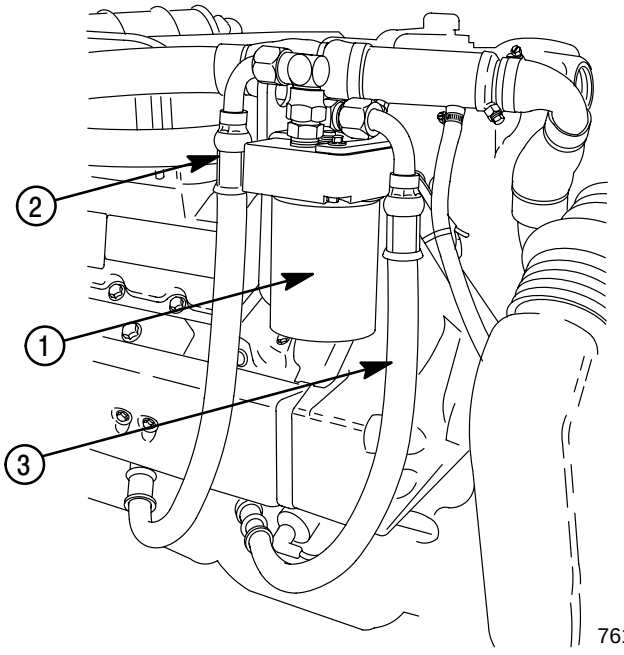
1. Install oil filter adapter beneath the bracket.
2. Secure adapter to bracket with two bolts. Tighten securely.



76219

1- Bolts

3. Connect oil hoses to oil filter adapter. Front hose comes from front fitting on block adapter. Rear hose comes from rear fitting. Tighten both securely.



76100

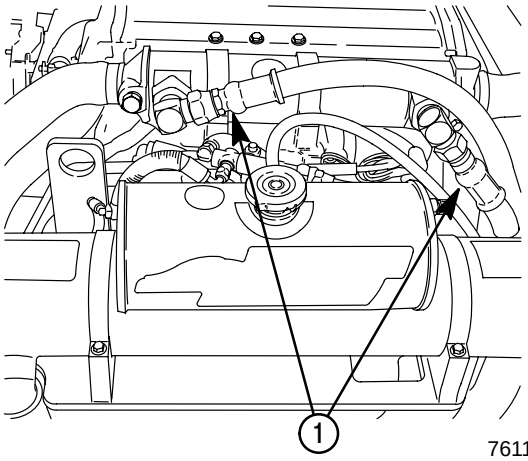
1- Oil Filter
2- Oil Hose To Block Adapter (Front)
3- Oil Hose To Block Adapter (Rear)

4. Install oil filter. Refer to previous procedure.

Oil Cooler

REMOVAL

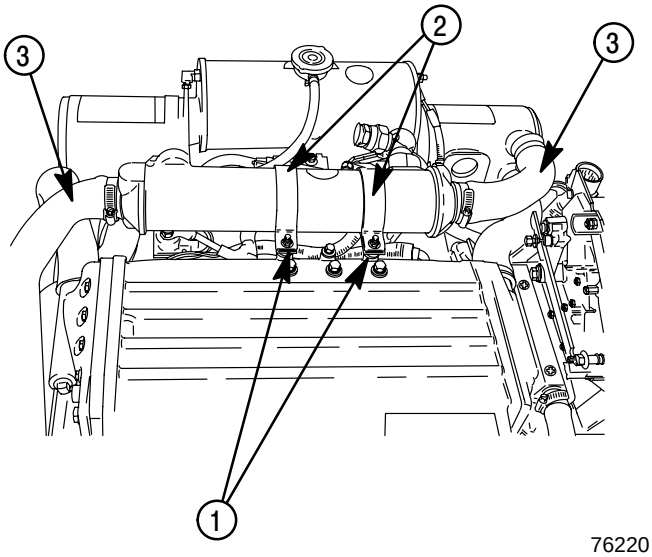
1. Drain seawater from cooling system. Refer to Section 6A for draining procedure.
2. Disconnect oil hoses from cooler.



76110

1- Oil Hoses

3. Remove seawater hoses from both ends of oil cooler.
4. Remove fasteners that secure cooler clamp bracket.



76220

1- Nuts
2- Clamp Brackets
3- Seawater Hoses

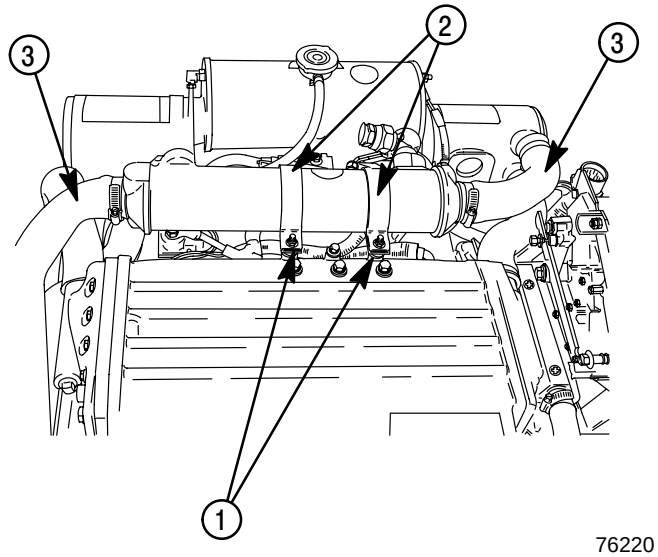
5. Remove cooler.

CLEANING AND INSPECTION

1. Refer to Section 6B for cleaning oil cooler.

INSTALLATION

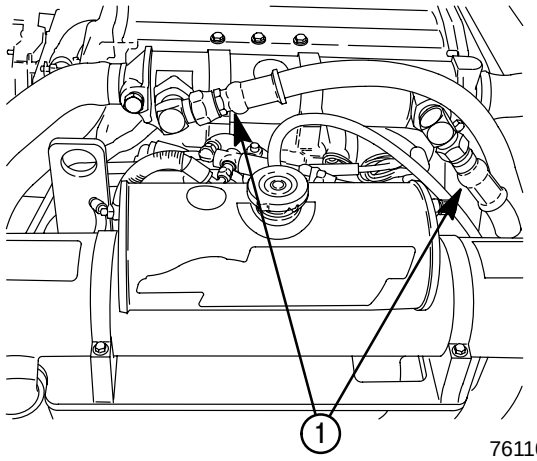
1. Install cooler.
2. Connect seawater hoses to both ends of oil cooler.
3. Install fasteners that secure cooler clamp bracket. Tighten nuts securely.



76220

1- Nuts
2- Clamp Brackets
3- Seawater Hoses

4. Connect oil hoses to cooler. Tighten securely.



76110

1- Oil Hoses

High Pressure Lube Oil System

High Pressure Pump Drive Gear Specifications

Gear Backlash	0.0055-0.0101 in. (0.140-0.256 mm)
End Play	0.018-0.48 in. (0.45-1.22 mm)

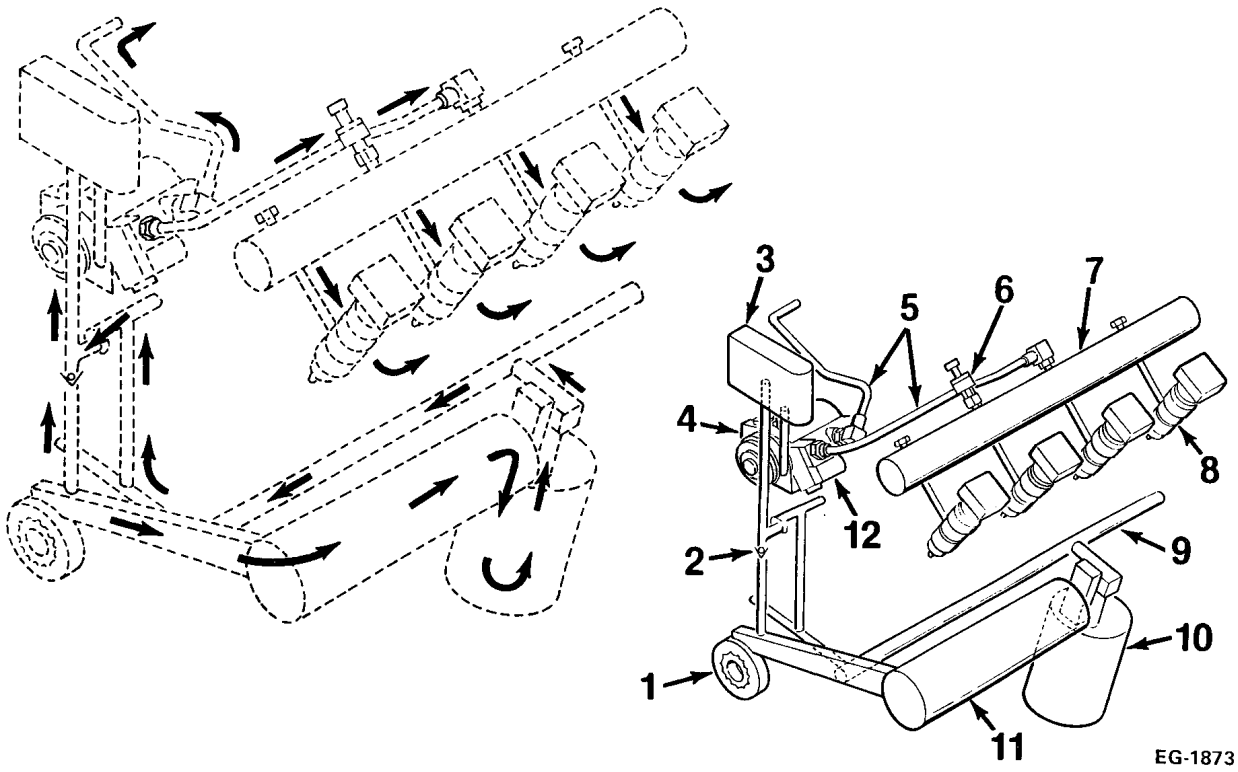
Special Torque Values

High Pressure Oil Pump Gear Bolt	95 lb.ft. (129 N·m)
Rail Pressure Control Valve Body	35 lb.ft. (47 N·m)
Rail Pressure Control Valve Nut	55 lbf-in (6 N·m)
High Pressure Hose Fitting (37 Degree Flare)	19 lb.ft. (26 N·m)
45 and 90 Degree Elbow Locknut	21 lb.ft. (28 N·m)

Special Service Tools

Tools	Description
ZTSE-4351	Hand Operated Vacuum Pump
ZTSE-4295	High Pressure Oil System Cap Set

Injector Oil System

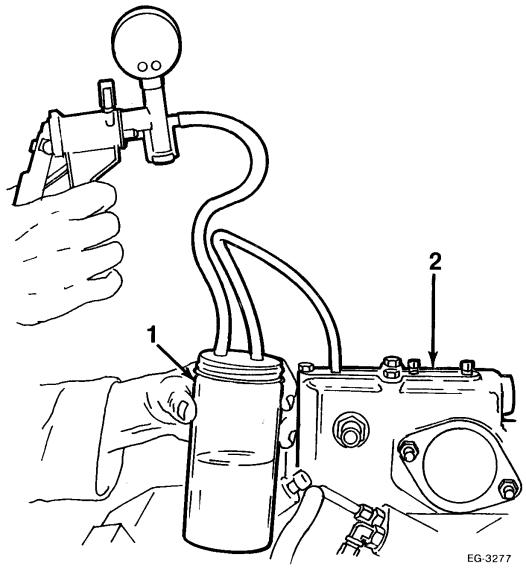


1-Oil Pump
2-Check Valve
3-Reservoir (Located On Top of Front Cover)
4-High Pressure Pump
5-High Pressure Lines
6-Injection Control Pressure Sensor
7-Cylinder Head High Pressure Rail
8-Fuel Injector (8)
9-Gallery (Crankcase)
10-Oil Filter
11-Oil Cooler
12-Injection Pressure Regulator Valve

Lube Oil Reservoir And High Pressure Pump Drive Gear

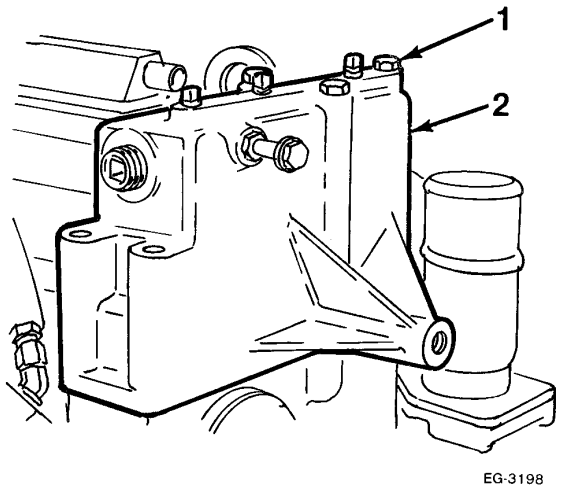
Removal

1. Remove 1/4 in. (6.35mm) pipe plug located on top left hand side of reservoir. Extract oil by inserting tube into reservoir from hand operated vacuum pump tool **ZTSE4351**.



1-Hand Operated Vacuum Pump
2-High Pressure Lube Oil Reservoir

2. Remove three (3) bolts securing high pressure reservoir to front cover.

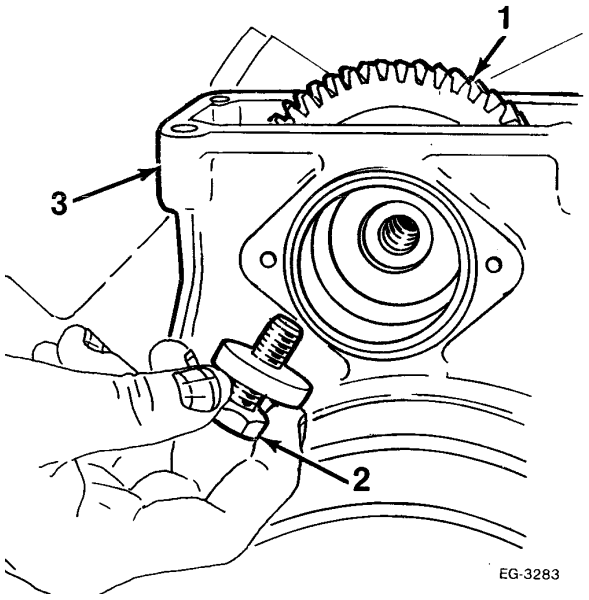


1-Reservoir Mounting Bolts
2-High Pressure Lube Oil Reservoir

3. Remove reservoir and gasket. Clean reservoir and crankcase front cover mating surfaces of all RTV sealant. Discard gasket.

4. Remove two (2) bolts securing high pressure pump access cover (located on the crankcase front cover, directly above water pump). Clean cover surface of all RTV sealant.

5. Remove bolt and washer securing high pressure pump drive gear to pump.

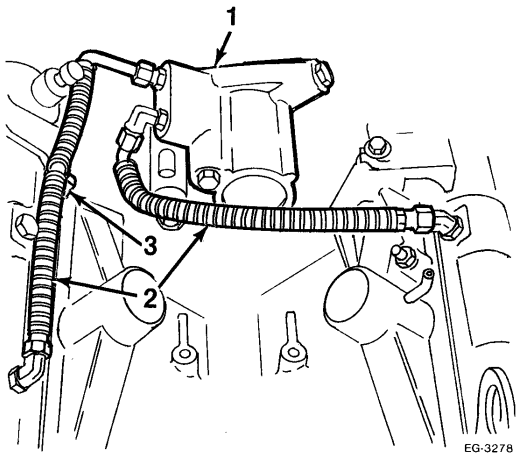


1-High Pressure Pump Drive Gear
2-Drive Gear Mounting Bolt & Washer
3-Crankcase Front Cover

High Pressure Pump

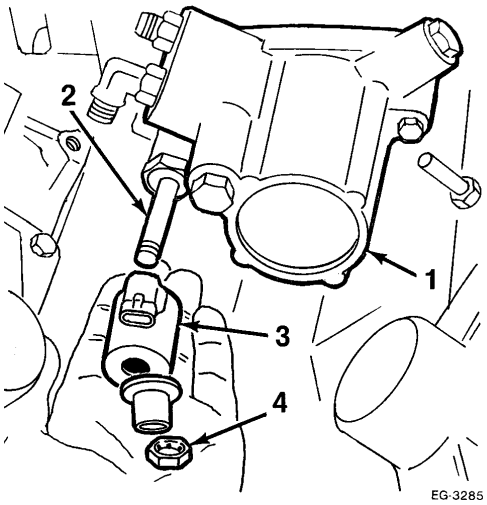
Removal

1. Loosen nuts securing both high pressure lube oil supply hoses at the pump and elbow fittings located on the cylinder head assemblies. Remove hoses with clamp.



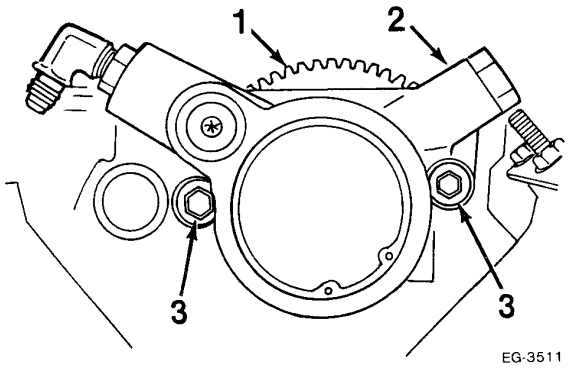
1-High Pressure Pump
2-Lube Oil Supply Hoses (2)
3-Hose Clamp

2. Cap high pressure pump fittings and cylinder head fittings using high pressure oil cap set **ZTSE4295**.
3. Remove tinnerman nut securing solenoid to injection control regulator. Remove solenoid.



1-High Pressure Oil Pump
2-Pressure Regulator
3-Solenoid
4-Tinnermann Nut

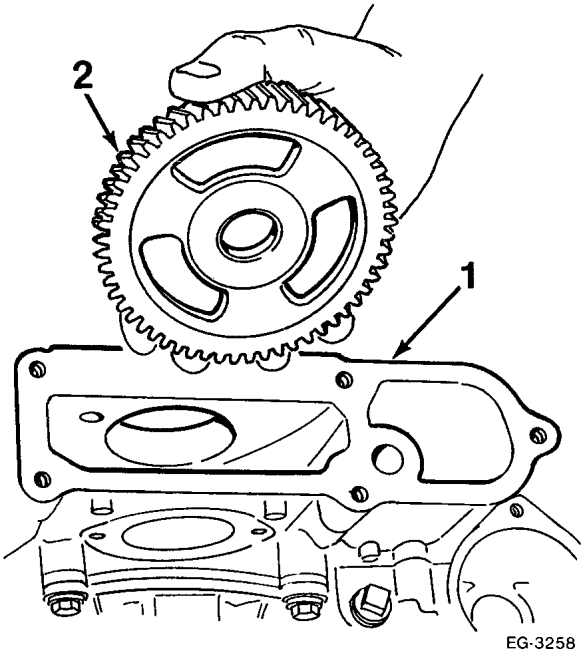
4. Remove two (2) capscrews securing high pressure lube pump to front cover. Remove pump and gasket from pump.



1-Drive Gear
2-High Pressure Lube Oil Pump
3-High Pressure Lube Oil Pump Mounting Bolts (2)

NOTE: *The high pressure pump gasket is reusable.*

5. Remove high pressure lube oil pump drive gear through top of front cover.

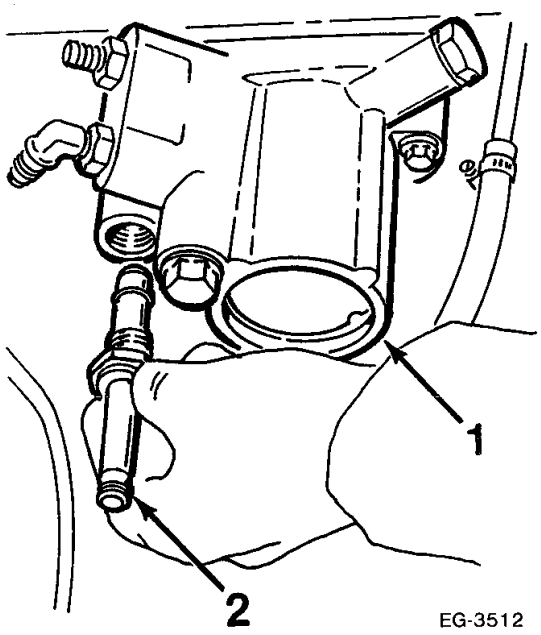


1-Drive Gear
2-Front Cover

Injection Control Pressure Regulator Removal (If Required)

NOTE: *Injection control pressure regulator can be removed, if required, before or after removing high pressure pump.*

1. Unscrew regulator valve from high pressure pump body using a 1-1/8 in. (28mm) deep wall socket.



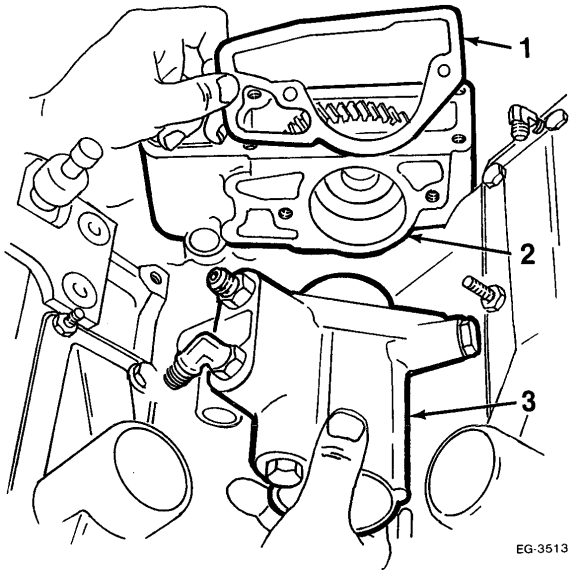
1-High Pressure Lube Oil Pump
2-Injection Control Pressure Regulator

Injection Control Pressure Regulator Reassembly (If Required)

1. Screw regulator valve into high pressure pump body using a 1-1/8 in. (28mm) deep wall socket.

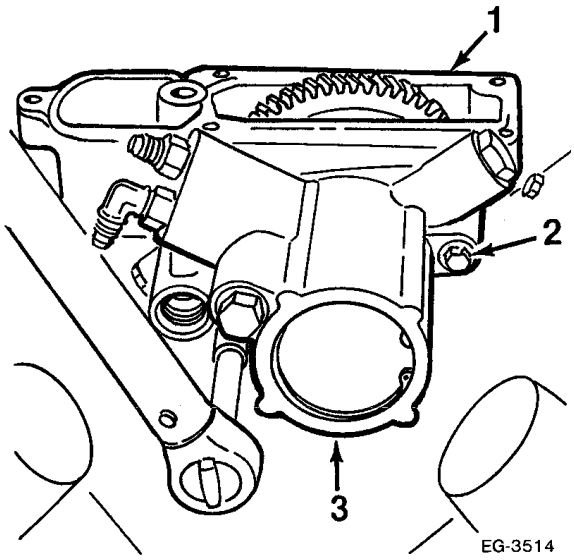
High Pressure Pump Reassembly

1. Insert pump drive gear into opening on top of front cover.



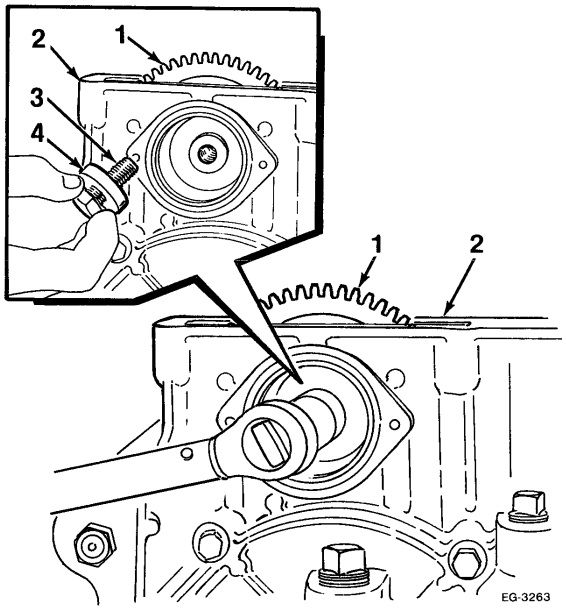
1-High Pressure Pump Gasket
2-Front Cover
3-High Pressure Pump

2. Position pump together with gasket against front cover and secure with two mounting bolts.



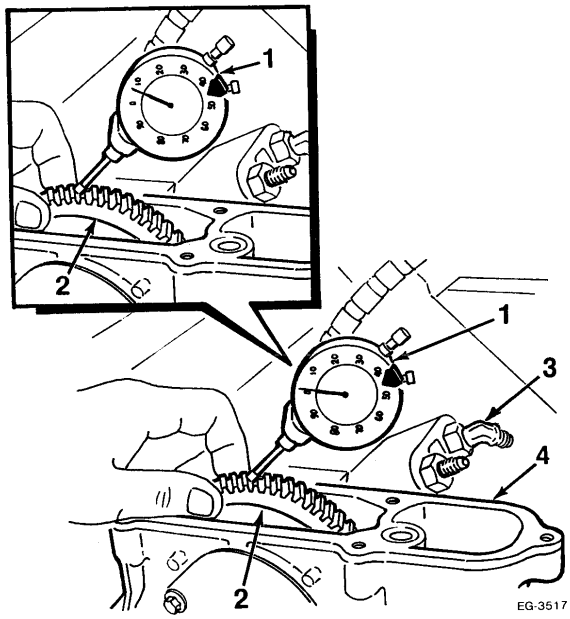
1-Front Cover
2-High Pressure Pump Mounting Bolts (2)
3-High Pressure Pump

3. Secure drive gear to pump using bolt and washer. Tighten to specified torque value.



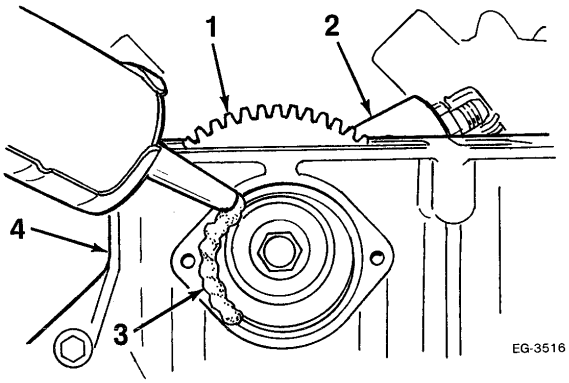
1-High Pressure Pump Drive Gear
2-Front Cover
3-Drive Gear Mounting Bolt
4-Washer

4. Check Drive Gear Backlash.
   a. Mount dial indicator.
   b. Zero the dial indicator.
   c. Place tip on gear tooth.
   d. Move gear by hand and record backlash.
   e. If backlash exceeds specified limits (see **SPECIFICATIONS**) gear should be replaced.



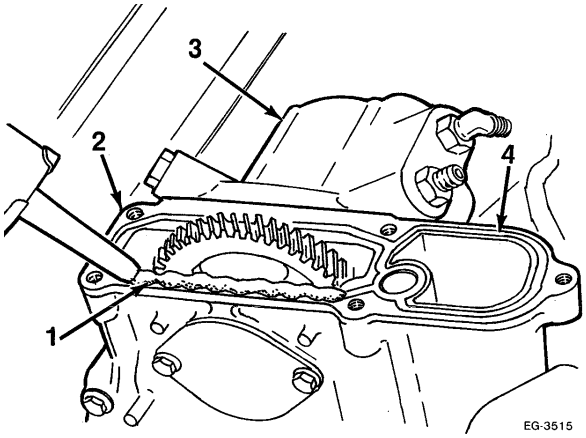
1-Dial Indicator
2-Drive Gear
3-High Pressure Pump
4-Front Cover

5. Secure access cover by applying RTV to front cover and threads of mounting bolts. Install two (2) mounting bolts. Tighten bolts.



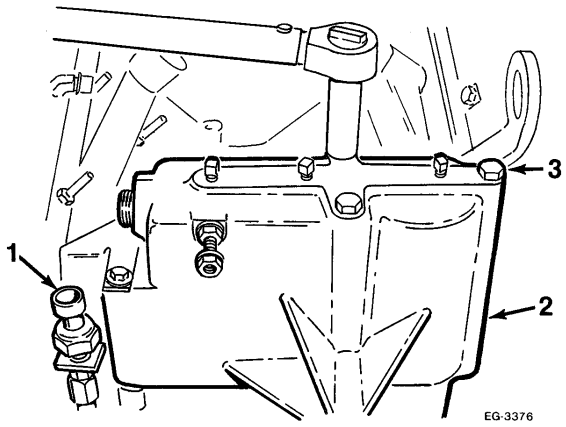
1-Drive Gear
2-High Pressure Pump
3-RTV Bead
4-Front Cover

6. Install new gasket onto top of reservoir mating surface.
7. Apply RTV around reservoir mating surface as shown.



1-RTV Bead
2-Front Cover
3-High Pressure Pump
4-O-Ring Gasket

8. Install reservoir to front cover and secure with three (3) bolts.

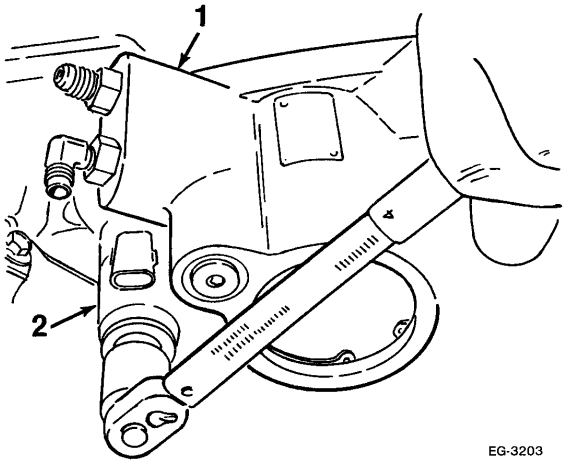


1-EBP Valve
2-Reservoir
3-Reservoir Mounting Bolts (3)

9. Tighten all reservoir mounting bolts to special torque value.

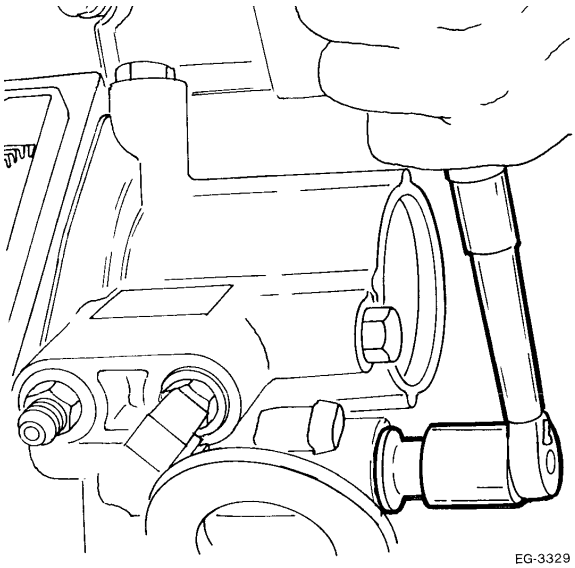
NOTE: *Fill reservoir with clean engine oil.*

10. If removed, install injection control pressure regulator and tighten to special torque value.



1-High Pressure Pump
2-Injection Control Pressure Regulator

11. Install and tighten tinnermann nut to special torque value.



Fuel System Specifications

Fuel Pressure Regulating Valve

Valve to Unseat At:	43 psi (6.2 kPa)

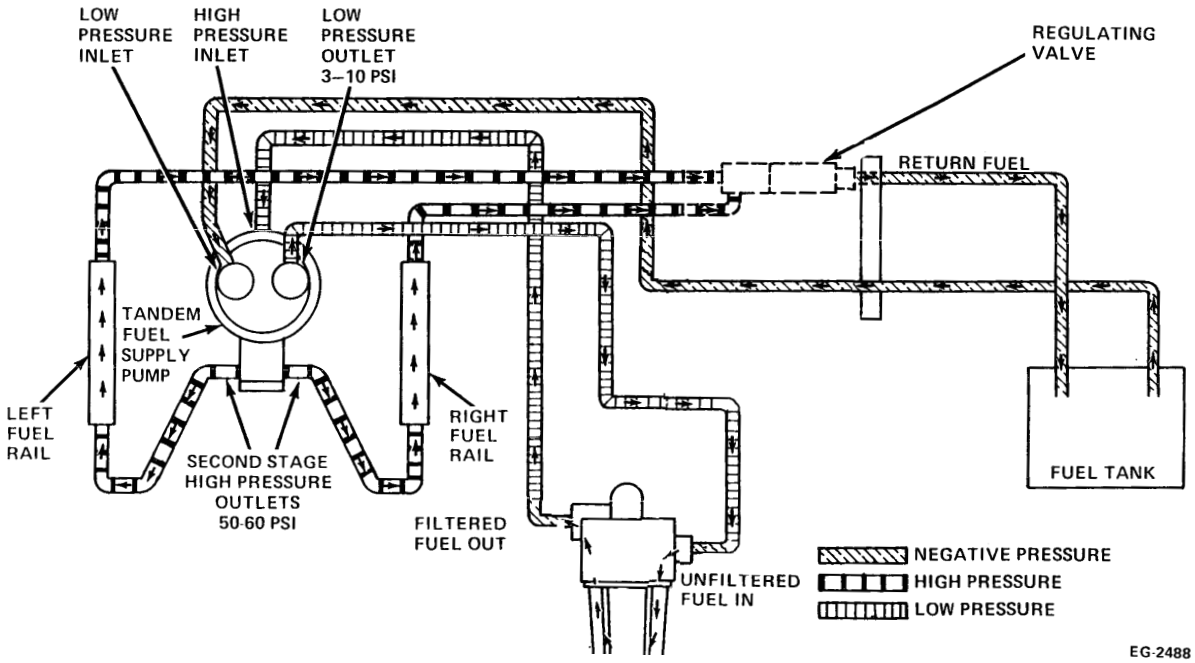
Special Torque Values

Injector Hold Down Bolt	105 lb.in. (12 N·m)
Fuel Return Hose Fitting	12 lb.ft. (16 N·m)
Fuel Supply Tube Bolt (Lift Pump Banjo Fitting)	40 lb.ft. (54 N·m)

Special Service Tools

Tools	Description
ZTSE-4294	Fuel System Cap Set

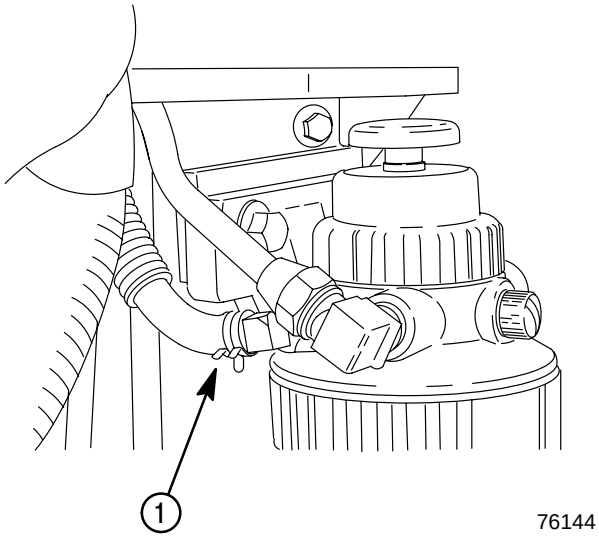
Fuel System Diagram



Fuel Filter Adapter

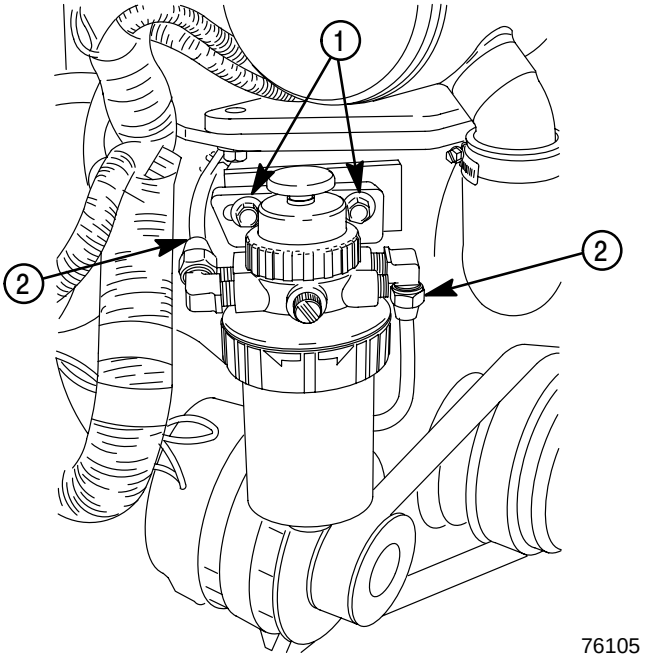
Removal

1. Drain fuel filter and remove it. Refer to SECTION 1B.
2. Disconnect flexible fuel line from filter adapter.



1 - Flexible Fuel Line

3. Disconnect metal fuel lines from both sides of filter adapter.
4. Remove bolts that secure fuel filter adapter.

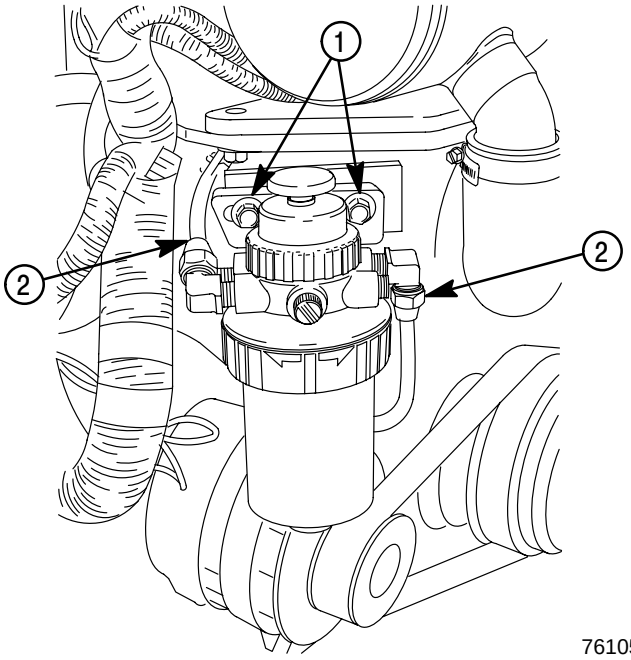


1 - Bolts
2 - Metal Fuel Lines

5. Remove filter adapter.

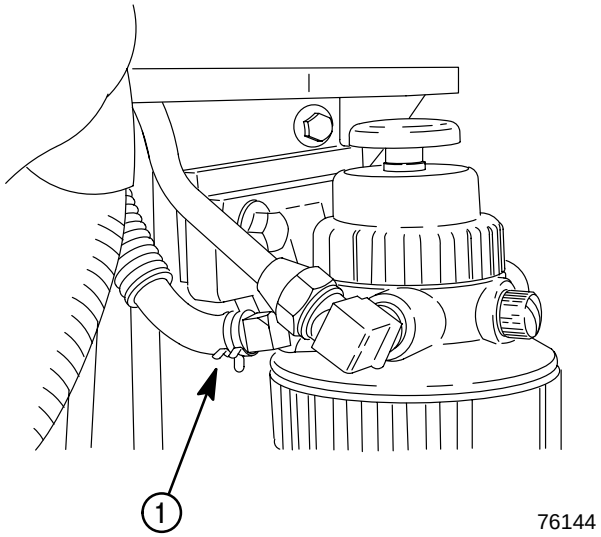
Installation

1. Install filter adapter.
2. Install bolts that secure fuel filter adapter.
3. Connect metal fuel lines to both sides of filter adapter. Tighten securely.



1 - Bolts
2 - Metal Fuel Lines

4. Connect flexible fuel line to filter adapter. Secure with clamp.



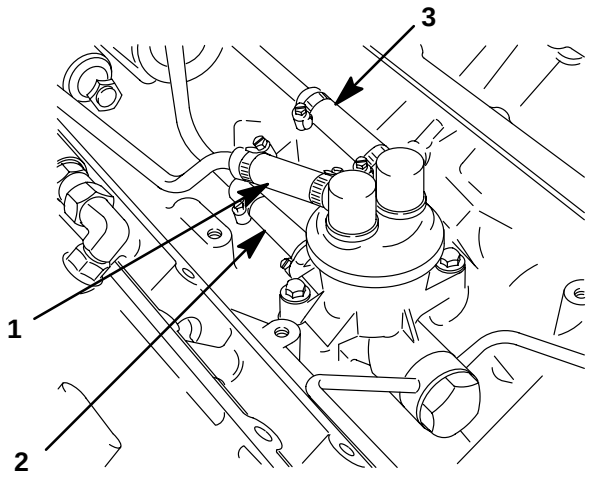
1 - Flexible Fuel Line

5. Refill and bleed air from fuel filter following procedure in SECTION 1B.

Tandem Lift Pump

Removal

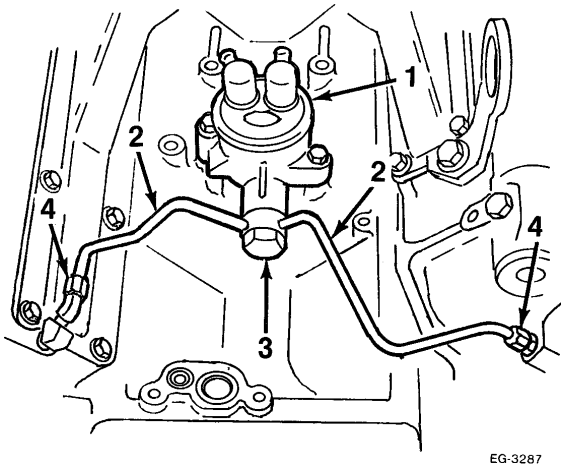
1. Remove the three fuel lines from the front side of pump. Make note of the position of the lines for later installation.



76183

1 - Fuel Inlet Line **From Tank**
2 - Fuel Outlet Line **To Filter**
3 - Fuel Inlet Line **From Filter**

2. Remove fuel supply tube banjo bolt and gaskets at base of tandem lift pump.
3. Loosen nuts of fuel supply tubes at cylinder heads and remove from engine.
4. Remove two (2) mounting bolts securing the tandem lift pump to base of crankcase. Remove tandem lift pump.
5. Retrieve tappet from pump bore in crankcase if required and insert into base of tandem pump.

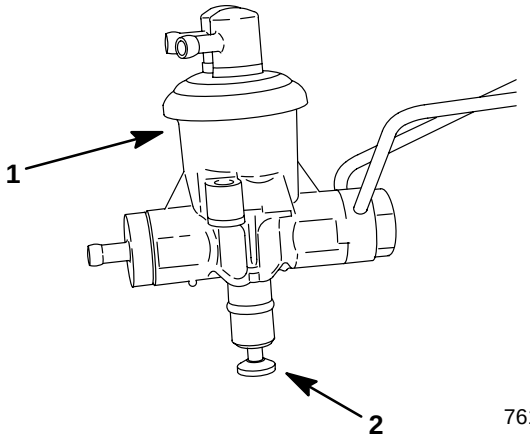


EG-3287

1 - Tandem Lift Pump
2 - Fuel Supply Tube to Cylinder Head Galleries
3 - Fuel Tube Banjo Bolt
4 - Fuel Supply Tube Nuts (2)

Inspection

1. Inspect tandem lift pump tappet for wear.

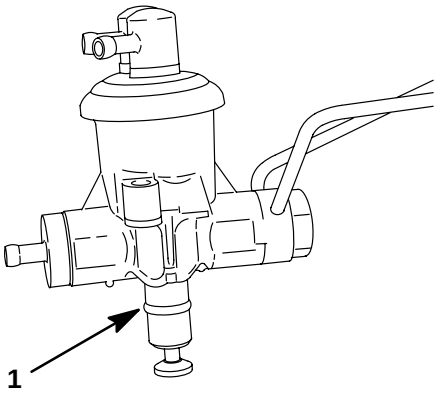


76184

1 - Tandem Lift Pump
2 - Tappet

Installation

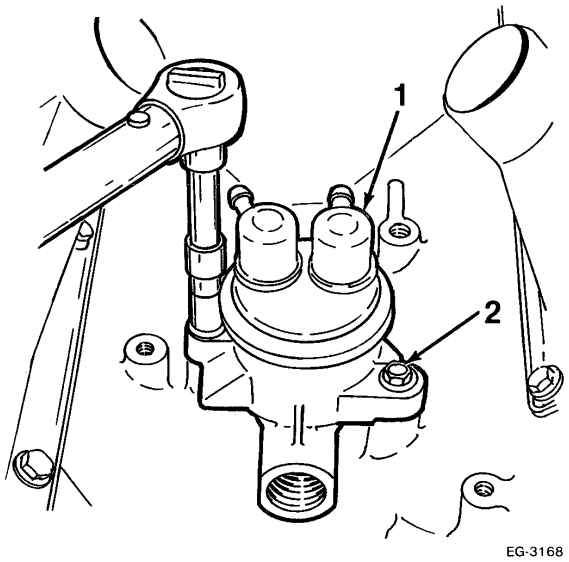
1. Install new O-Ring on tandem lift pump.



76184

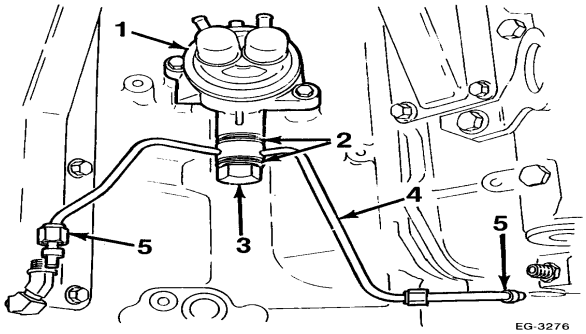
1 - O-Ring

2. Install tandem lift pump to crankcase using two (2) mounting bolts and torque to specified torque.



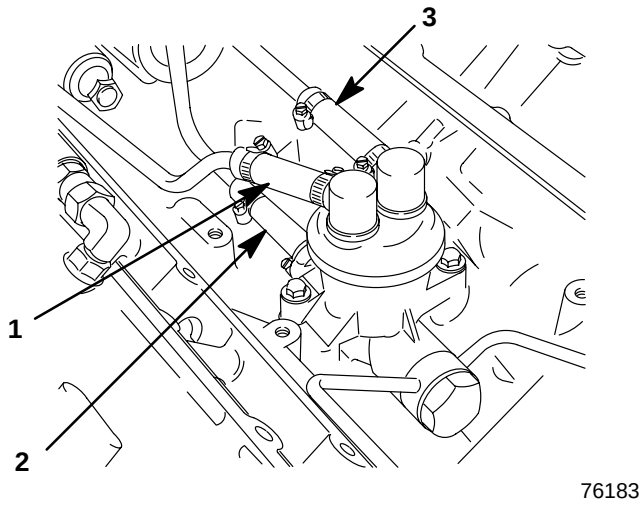
1 - Tandem Lift Pump
2 - Tandem Lift Pump Mounting Bolts (2)

3. Place seal rings onto fuel supply tube bolt and position bolt onto fuel supply tube.
4. Install fuel supply tube, bolt and gaskets to tandem lift pump. Tighten bolt to specified torque.
5. Attach fuel supply tube nuts to cylinder head elbows and tighten to standard torque value.



1 - Tandem Lift Pump
2 - Seal Rings
3 - Fuel Supply Banjo Bolt
4 - Fuel Supply Tube
5 - Fuel Supply Tube Nuts (2)

6. Install the three fuel lines on the front side of pump. Make sure that the lines are connected to the proper fitting.



1 - Fuel Inlet Line **From Tank**
2 - Fuel Outlet Line **To Filter**
3 - Fuel Inlet Line **From Filter**

Injectors

REMOVAL

NOTE: *Refer to "CYLINDER HEAD AND VALVES" for injector removal and installation instructions.*

Torque Data

General Torque Guidelines

Many conditions affect torque and the results of torque applications. The major purpose in tightening a fastener to a specified torque is to obtain tension in the fastener (i.e., bolt, nut, etc.), which in turn develops a clamping load which exceeds any possible loading imposed on parts due to engine RPM or vibration.

Tension Values for Standard Fasteners

The “Standard Nut and Bolt Torque Chart” provides tightening torque for general purpose applications using original equipment standard hardware as listed in the Parts Catalog for the application involved. **DO NOT SUBSTITUTE**. Original equipment standard hardware is defined as Type 8, coarse thread bolts and nuts and thru hardened flat washers (Rockwell “C” 38-45), all phosphate coated and assembled without supplemental lubrication (as received condition).

NOTE: *Phosphate coating is a dry lubricant.*

Fastener Thread Condition

Threads that are dry, excessively rough, battered or filled with dirt require considerable effort just to rotate. Then; when the clamping load is developed or the bolt tension is applied, the torque reading mounts rapidly (due to thread friction) to the specified torque value. However, the desired bolt tension and maximum clamping effect is not achieved. This condition can lead to failure of the fastener to maintain component integrity. The proper bolt tension and clamping effect can never be attained if the fastener is dry. The fastener threads must have a film of clean lubricant (engine oil) to be considered lubricated.

Standard Nut And Bolt Torque Chart

Hex Flange Head			
Thread Diameter	**Torque lbf.ft.**	**Torque Nm**	**Wrench Size (mm)**
M6x1	8	11	8
M8x1.25	18	24	10
M10x1.5	36	49	13
M12x1.75	61	83	15
M16x2	154	208	21

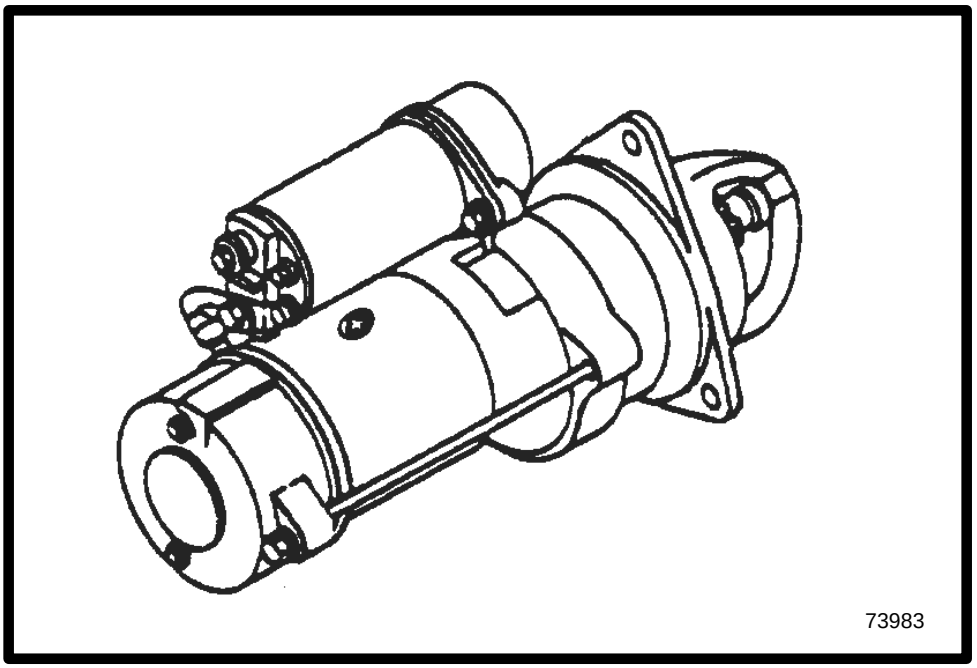
Hex Head			
Thread Diameter	**Torque lbf.ft.**	**Torque Nm**	**Wrench Size (mm)**
M6x1	6	8	10
M8x1.25	15	20	13
M10x1.5	30	40	16
M12x1.75	51	69	18
M16x2	128	173	24

NOTE: *For special torques, refer to “Special Torque Values” in specific component areas of this section.*

ELECTRICAL SYSTEMS

4

A



STARTING SYSTEM

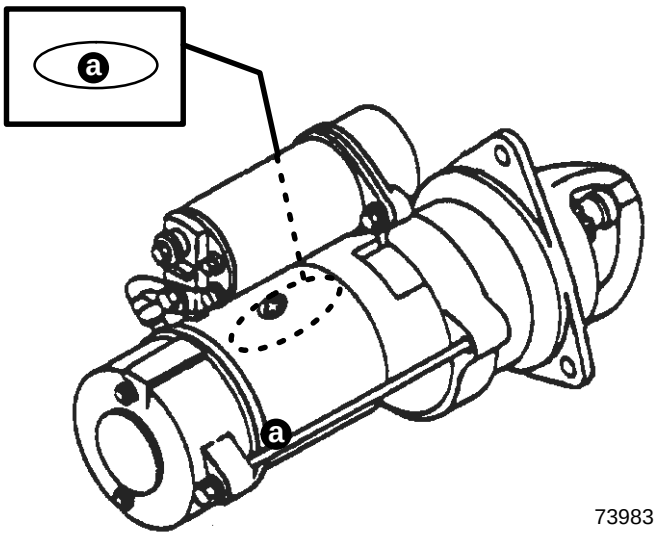
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Identification

The starter identification number is located as shown.



73983

a - Starter Identification Number

Delco Remy 28MT Series Starter

Specifications

Delco Remy 28MT Series Starter

Delco Remy Identification Number	Rotation	No Load Test				
		Volts	Min. Amps	Max. Amps	Min. RPM	Max. RPM
1113276	Clockwise	10	125	190	3000	5600
Commutator Diameter[1]	Service Limit	1.378 in. (35 mm)				
Minimum Brush Length		.472 in. (12 mm)				

[1] : Do not turn commutator in a lathe.

Torque Specifications

Fastener Location	Lb. Ft. (N·m)	Lb. In. (N·m)
Starter Mounting Bolts	50 (68)	
Battery Cables	Securely	

Lubricants/Sealants

Part Number	Description
92-25711	Quicksilver Liquid Neoprene
196094 (Obtain Locally)	Delco Remy Lubricant (for 28MT)
Obtain Locally	SAE 10W Oil (for Bosch)

Replacement Parts Warning

⚠WARNING

Electrical, ignition and fuel system components on your MerCruiser are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.

Use of replacement electrical or fuel system components, which do not comply with these rules and regulations, could result in a fire or explosion hazard and should be avoided.

Battery

IMPORTANT: Boating industry standards (BIA, ABYC, etc.) federal standards and Coast Guard regulations must be adhered to when installing or replacing battery or cables. Be sure battery cable installation meets the pull test requirements and that positive battery terminal is properly insulated in accordance with regulations.

IMPORTANT: Engine electrical system is negative (-) ground. It is recommended (required in some states) that battery be installed in an enclosed case. Refer to regulations for your area.

Battery Cable Recommendations

IMPORTANT: Terminals must be soldered to cable ends to ensure good electrical contact. Use electrical grade (resin flux) solder only. Do not use acid flux solder, as it may cause corrosion and failure.

Battery Cable Length	Minimum Cable Gauge
Up to 3 ft. (0.9m)	2 (35mm^2)
3 - 3-3/4 ft. (0.9 - 1.1m)	1 (50mm^2)
3-3/4 - 4-3/4 ft. (1.1 - 1.4m)	0 (50mm^2)
4-3/4 - 6 ft. (1.4 - 1.8m)	00 (70mm^2)
6 - 7-1/2 ft. (1.8 - 2.3m)	000 (95mm^2)
7-1/2 - 9-1/2 ft. (2.3 - 2.9m)	0000 (120mm^2)
9-1/2 - 12 ft. (2.9 - 3.7m)	▲ 00 (70mm^2)
12 - 15 ft. (3.7 - 4.6m)	▲ 000 (95mm^2)
15 - 19 ft. (4.6 - 5.8m)	▲ 0000 (120mm^2)
▲ :Two cables of specified gauge required for positive and two required for negative.	

1. Select a battery that meets all of the following specifications:
   a. 12-volt marine type.
   b. Tapered post connectors or side terminal connectors (Do not use a battery with wing nut connectors).
   c. Battery capacity rating of at least:

Minimum 12V Battery Capacity Rating	
All Models	300 Amp Hour or 1500 Cold Cranking Amps

Maintenance

⚠WARNING

Hydrogen gases that escape from the battery during charging are explosive. Be sure that battery area is well ventilated and that bilge blower is in operation when charging. DO NOT smoke or allow sources of spark or open flame in area when charging battery.

⚠WARNING

Battery electrolyte is a corrosive acid and should be handled with care. If electrolyte is spilled or splashed on any part of the body, immediately flush the exposed area with liberal amounts of water and obtain medical aid as soon as possible. Safety glasses and rubber gloves are recommended when handling batteries.

⚠CAUTION

To prevent damage to the electrical system be sure to adhere to the following:

- **When installing battery, be sure to connect the positive (+) battery cable to positive (+) battery terminal first and then the negative (-) battery cable to negative (-) battery terminal.**
- **Never disconnect the battery cables while the engine is running.**
- **If a charger or booster is to be used, be sure to connect it in parallel with existing battery (positive to positive and negative to negative).**
- **When applying a booster charge to battery, disconnect both cables from battery (to prevent damage to voltage regulator).**
- **Check battery condition periodically.**
- **Make sure that battery leads are kept clean and tight.**

Testing

⚠WARNING

Do not use jumper cables and a booster battery to start engine. Damage to various electrical components may occur. Do not recharge a weak battery in the boat. Remove battery and recharge in a ventilated area away from fuel vapors, sparks or flames.

⚠CAUTION

Test battery in well ventilated area as gases given off by battery are hazardous.

Place battery under heavy load (as during engine cranking or with a variable resistor tester) and test cell voltage while under load.

Certain conditions must be met before testing.

- Battery must be 60 to 100°F (16 to 38°C).
- Electrolyte level must be correct in all cells.
- Battery must be at least half charged.
- No obvious defects.

2. Check voltage per manufacturer's specifications.
3. If readings are low, recharge and retest.
4. If readings remain low, battery should be replaced.

Storage

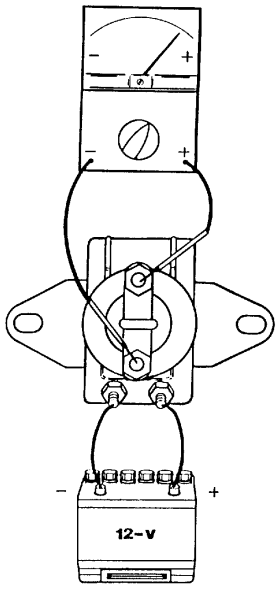
1. Remove battery and clean exterior.
2. Check fluid level and fill if low.
3. Cover terminals and bolts with light coat of grease.
4. Set battery on wood or in carton; store in cool, dry place.
5. Check every 20 days for fluid level and slow charge.

IMPORTANT: A discharged battery can be damaged by freezing.

Standard Starter Slave Solenoid

Testing/Replacement

1. Using continuity meter, connect test leads as shown, and connect 12 volt battery with jumper leads as shown.

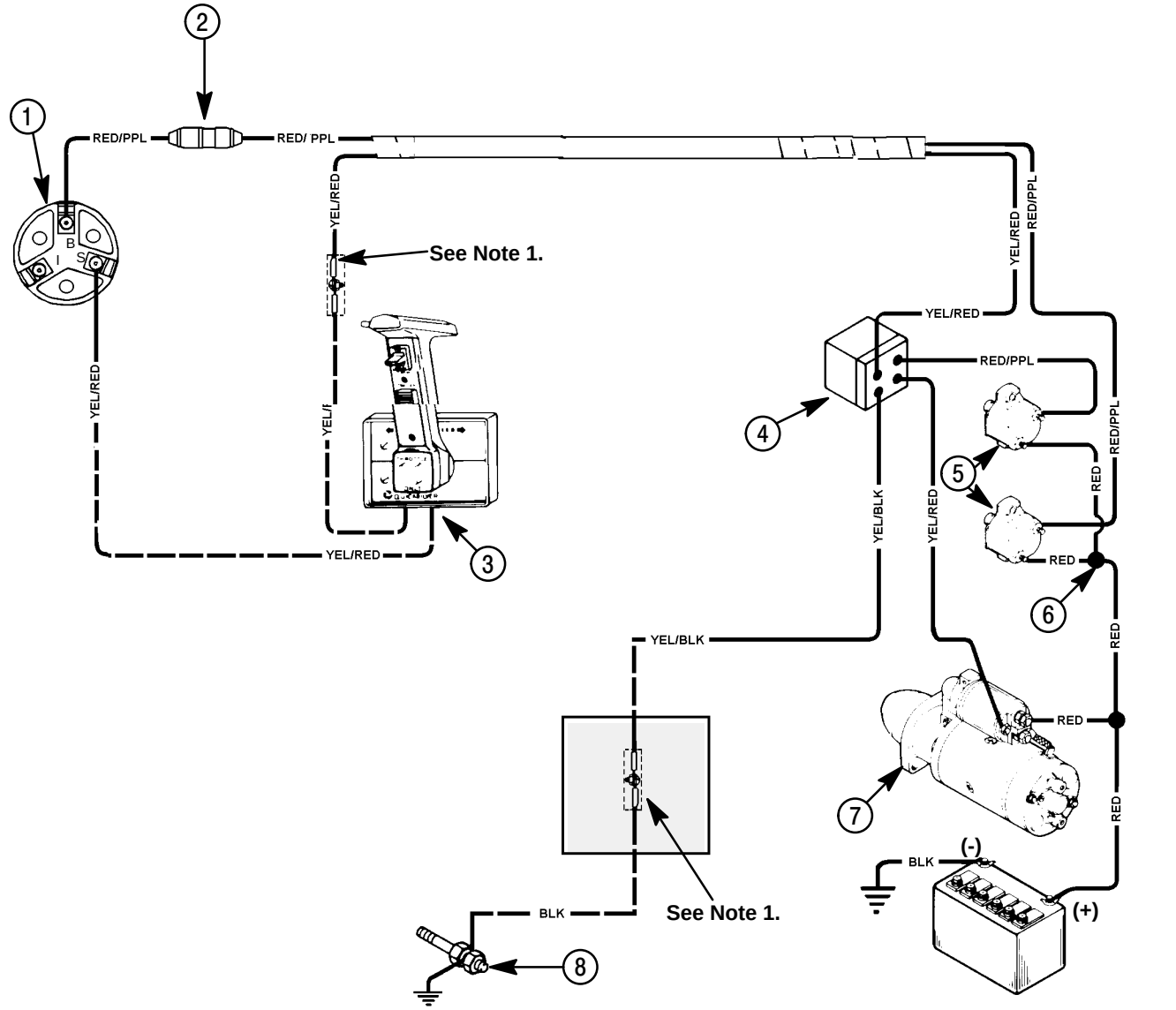


72630

Typical

2. If no meter movement is present, replace slave solenoid.

Starting System Components



76208

1 - Ignition (Start/Stop) Switch
2 - 20 Ampere Fuse
3 - Remote Control Neutral Safety Switch [MCM (Stern Drive) Only)
4 - Start Relay
5 - Circuit Breaker(s)
6 - Wire Junction
7 - Starter Motor
8 - Ground Stud

Note 1. : *Wires connected together with hex screw and nut, coated with liquid neoprene and protected by a rubber sleeve.*

Positive Current Flow

This is a general description of the positive current flow, from the battery and through the system until the starter motor cranks.

- **Battery to the solenoid switch (on starter) (RED battery cable).**
- **Solenoid switch to circuit breaker (RED).**
- **Circuit breaker to wire junction (RED-PUR).**
- **Wire junction to wiring harness plug (RED-PUR) terminal 10.**
- **Wiring harness plug to 20 amp fuse (RED-PUR).**
- **20 amp fuse to ignition switch terminal B (RED-PUR). At this point ignition switch is turned to START.**
- **Ignition switch terminal B to terminal S.**
- **Ignition switch terminal S to wiring harness plug (YEL-RED) terminal 4.**
- **Wiring harness plug to starter relay (YEL-RED).**
- **Starter relay to neutral start switch (YEL-BLK). NEUTRAL START SWITCH MUST BE AT NEUTRAL POSITION.**
- **Ensure black is grounded from neutral start switch. Starter relay is now "closed," completing circuit between large terminal (RED-PUR) and other large terminal (YEL-RED), causing starter motor to crank.**

Delco Remy 28MT Series Starter

Description

The 28-MT Cranking Motor provides high starting torque in a compact, lightweight package by using a high speed motor through an offset gear reduction unit. Weighing just 8 kg (17.6 lb), the 28-MT produces up to 3 kilowatts of output.

The 28-MT has a totally enclosed, solenoid operated mechanism for positive shift of the pinion into engagement. The solenoid is sealed to prevent entry of foreign material. Within the solenoid, waffle-type contact faces and a solid link between the contact disc assembly and the solenoid plunger help prevent contact sticking. The shift lever is attached to the plunger on one end and mates with a collar on the drive assembly at the other end. The action of the lever forces the drive pinion into engagement with the engine flywheel when the magnetic pull of the solenoid draws the plunger in.

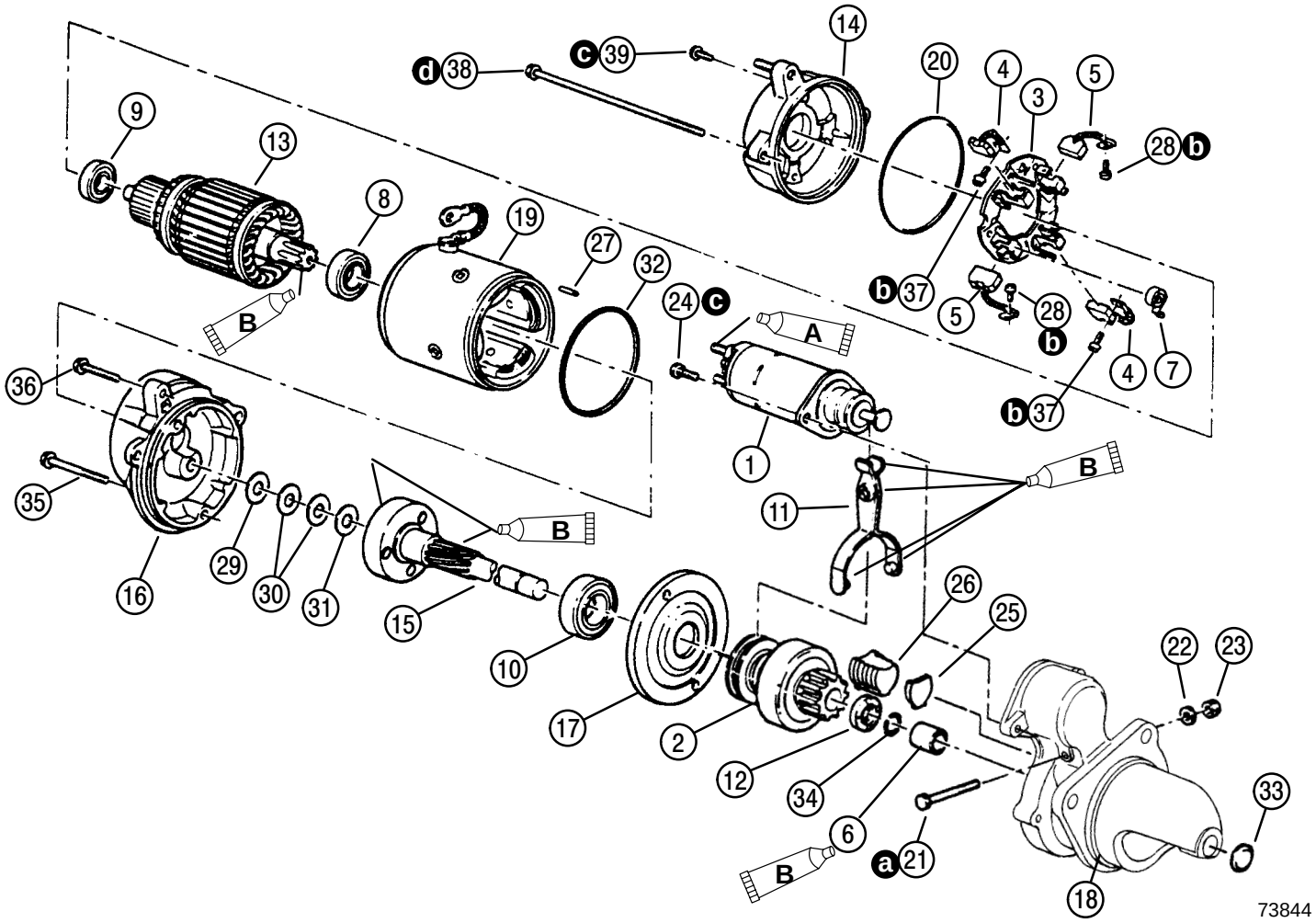
A medium-duty, 5-roll overrunning drive is used for low overrun friction and long operating life. The drive shaft is supported by a ball bearing at the gear reduction end and by a sleeve bushing at the drive end. An external helical spline on the drive shaft turns the pinion as it moves into engagement with the engine flywheel. An internal gear at the gear reduction end of the drive shaft is driven by the armature shaft gear at a speed of one drive shaft revolution for each 3.875 revolutions of the armature.

The 28-MT armature is dynamically balanced and rides in sealed ball bearings at each end. Steel banding and varnish impregnation are used for added armature strength. The molded-bar commutator receives electrical power through radially positioned, one-piece brushes. Constant-pressure brush springs are used for even brush wear and long brush life.

⚠CAUTION

The starter motor is designed to operate under great overload and produce a high horsepower for its size. It can do this only for a short time, since considerable heat accumulates and can cause serious damage. For this reason, the cranking motor must never be used for more than 15 seconds at any one time. Cranking should not be repeated without a pause of at least 1 minute to permit the heat to escape.

Exploded View



1 - Solenoid Assembly
2 - Clutch Drive Assembly
3 - Brush Holder Assembly
4 - Brush (Grounded)
5 - Brush (Insulated)
6 - Drive End Housing Bushing
7 - Brush Spring
8 - Drive End Armature Bearing
9 - Commutator End Armature Bearing
10- Center Support Bearing
11- Shift Lever
12- Pinion Stop
13- Armature
14- Commutator End Frame
15- Drive Shaft
16- Armature Support Bracket
17- Drive Shaft Support
18- Drive Housing
19- Frame and Field Assembly
20- Commutator End Frame O-Ring
21- Shift Lever Screw
22- Shift Lever Washer
23- Shift Lever Nut
24- Solenoid Screw (2)
25- Plate (If Used)
26- Drive Housing Plug
27- Dowel Pin
28- Insulated Brush Screw (2)
29- Washer (Fiber)
30- Washer (Thin; One or Two May Be Used)
31- Washer (Thick)
32- Frame Seal
33- Bushing Plug
34- Stop Ring
35- Drive Housing Bolt (Long)
36- Drive Housing Bolt (Shorter On Some Models)
37- Grounded Brush Screw (2)
38- Thru Bolt (2)
39- Brush Plate Screw (2)

Lubricant/Sealant Application Points

A Quicksilver Liquid Neoprene - 92-25711

B Delco Remy Lubricant Number 196094

Torque Specifications

a 40 lb. in. (4.5 N·m)
b 13 lb. in. (1.5 N·m)
c 25 lb. in. (2.8 N·m)
d 75 lb. in. (8.5 N·m)

Delco Remy 28MT Starter Motor - MCM (Stern Drive)

Periodic Inspection

Cranking motor and solenoid are completely enclosed in the drive housing to prevent entrance of moisture and dirt. However, periodic inspection is required as follows:

1. Inspect terminals for corrosion and loose connections.
2. Inspect wiring for frayed and worn insulation.
3. Check mounting bolts for tightness.

Starter Motor Repair

⚠WARNING

Always disconnect battery cables from battery before working around electrical system components to prevent injury to yourself or damage to electrical system.

IMPORTANT: Always install fasteners at original location. If necessary to replace fasteners, use only correct part number or equivalent. If correct part number is not available use only a fastener of equal size and strength. Use a torque wrench to tighten fasteners when a torque value is specified in these instructions. Torques specified are for dry, unlubricated fasteners unless otherwise specified.

Starter Removal

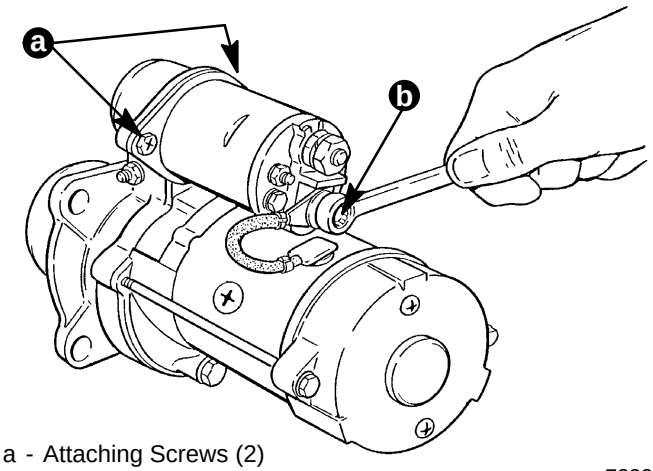
⚠WARNING

Disconnect battery cables at battery before removing starter.

1. Disconnect battery cables from battery.
2. Disconnect wires from solenoid terminals.
3. Remove starter mounting bolts.
4. Pull starter assembly away from flywheel and remove from engine.

Solenoid Removal

1. Remove starter motor as outlined.
2. Remove nut from field coil connector and solenoid attaching screws.



a - Attaching Screws (2)
b - Field Coil Nut

73235

3. Twist solenoid to disengage tab, and remove.

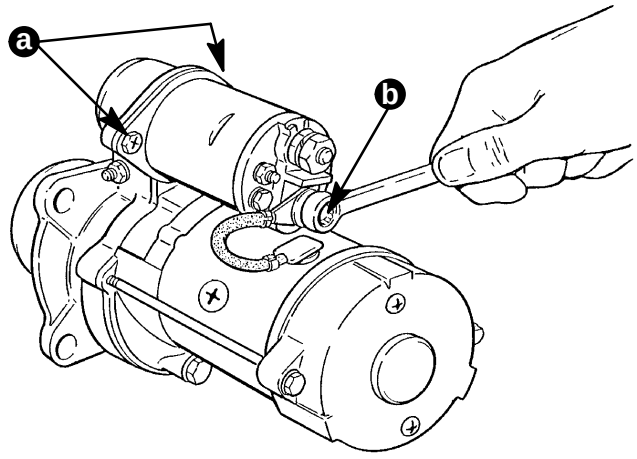
Solenoid Installation

1. Install solenoid onto plunger.
2. Twist solenoid to engage tab.
3. Install screws and tighten securely.
4. Install field coil connector nut.

Starter Motor Disassembly

1. Remove nut from field coil connector and solenoid attaching screws.

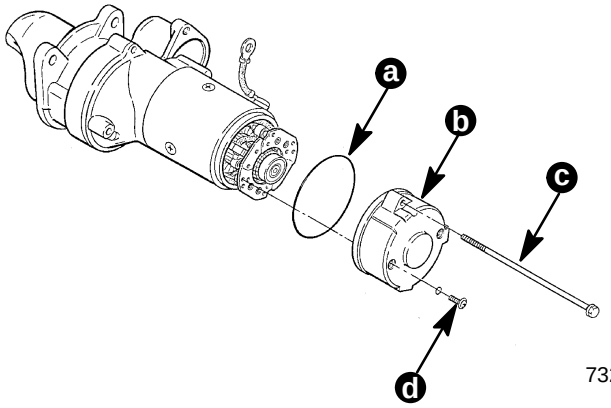
2. Twist solenoid to disengage from shift lever and remove from drive housing.



73235

a - Attaching Screws (2)
b - Field Coil Nut

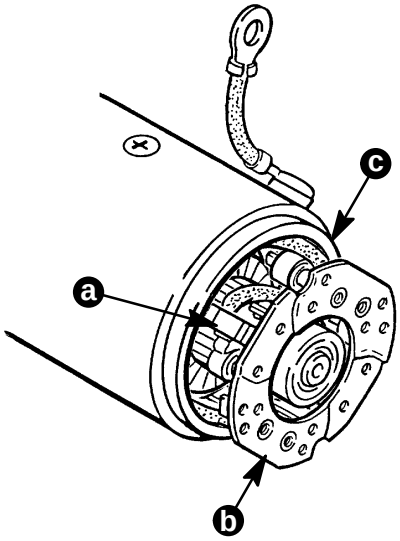
3. Remove end frame thru bolts and two Phillips screws. Remove end frame with O-ring.



73267

a - O-Ring
b - End Frame
c - Thru Bolt
d - Phillips Screw

4. Remove two brushes from brush holder connected to field frame. Remove brush holder from commutator.



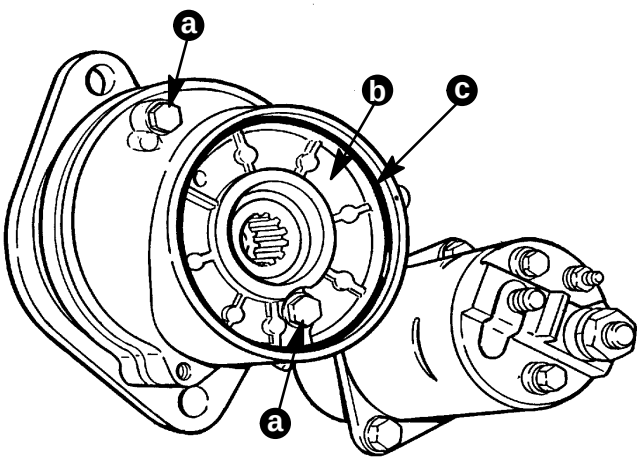
73245

a - Brush (2)
b - Brush Holder
c - Field Frame

IMPORTANT: In the following step, use care not to lose the small dowel pin installed between frame and field assembly and the armature support bracket (refer to "Exploded View"). Dowel pin is required for assembly and must be saved. If dowel pin should be lost, it must be replaced with 2 mm (0.079 in.) diameter x 10 mm (0.394 in.) long pin procured or manufactured locally.

5. Remove field frame and armature from armature support bracket.

6. Remove the two screws indicated. Then remove the armature support bracket with rubber gasket.

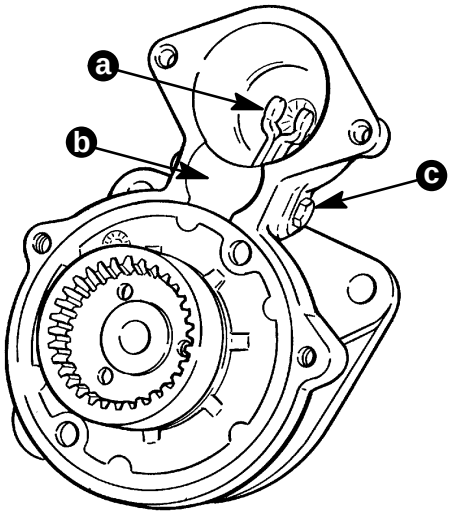


73236

a - Screws
b - Gear Cover
c - Rubber Gasket

NOTE: *Armature assembly may come off with frame or may be retained by gear reduction and drive group.*

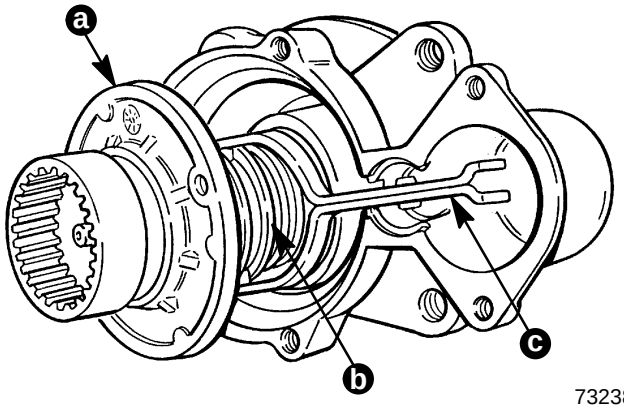
7. Remove armature assembly and bearing, if it did not come loose with the frame and field.
8. Remove shift lever retainer and bolt securing shift lever.



73237

a - Shift Lever
b - Retainer
c - Bolt

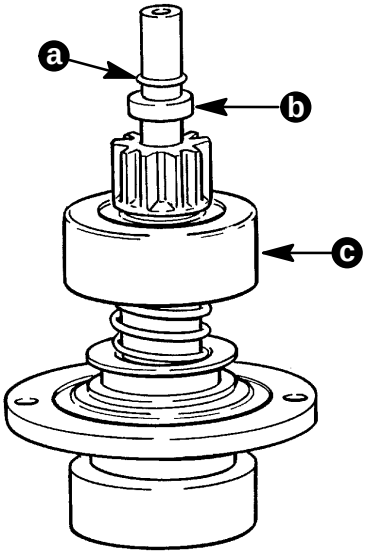
9. Pull drive assembly and shift lever from drive housing.



73238

a - Bearing Plate
b - Drive Assembly
c - Shift Lever

10. Remove collar and retaining ring from drive assembly.



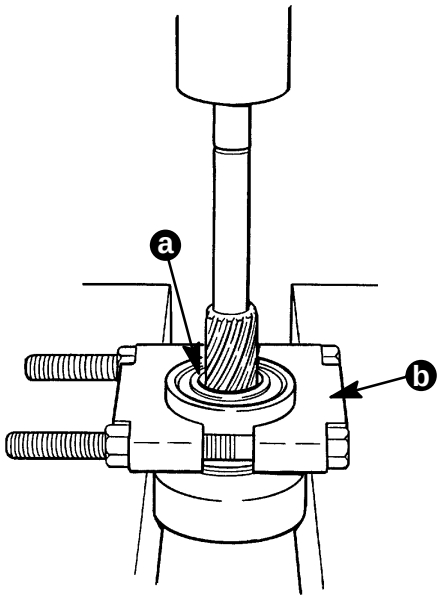
73239

a - Retaining Ring
b - Collar
c - Driver Assembly

11. Twist drive assembly from drive shaft.
12. Use a universal puller plate and press to remove drive shaft bearing if replacement is necessary. Refer to “Cleaning and Inspection”. Do not remove the ball bearings unless replacement is required.

⚠ CAUTION

Avoid unnecessary replacement of bearings. Ball bearings which are removed from drive shaft MUST BE replaced with new bearings. Removal procedure causes internal damage to bearings. Do not remove bearings from armature assembly unless replacement IS required.



73240

a - Drive Shaft Bearing
b - Plate Puller

NOTE: *Armature bearings may be removed, when necessary, in same manner.*

Cleaning and Inspection

With starting motor completely disassembled, except for removal of field coils, component parts should be cleaned and inspected. Field coils should be removed only where defects are indicated by tests. Defective parts should be replaced or repaired.

Clean all parts with a soft cloth prior to testing or inspection.

IMPORTANT: DO NOT use grease dissolving solvents for cleaning over-running clutch, armature and field coils. Such a solvent would dissolve grease packed in clutch mechanism and damage armature and field coil insulation.

Do a thorough inspection of:

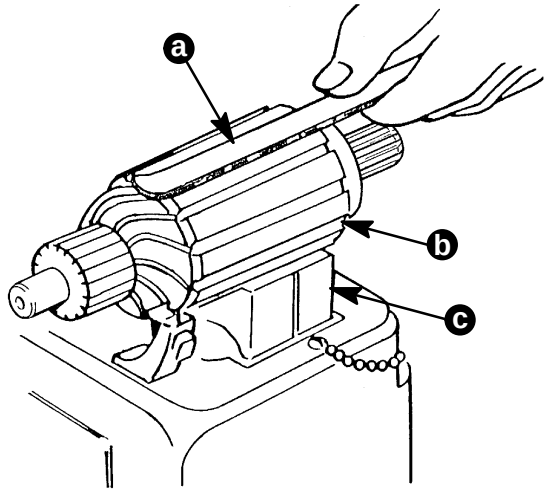
1. All parts for cracks, distortion or other structural damage. Replace parts or assemblies which are cracked, bent or otherwise damaged.
2. Threaded parts for stripped, crossed or otherwise damaged threads. Replace parts with thread damage that cannot be cleaned up using a suitable tap or die. Replace any hardware items that have damaged threads.
3. Solenoid assembly for cut or torn boot. If boot is damaged, replace solenoid assembly.
4. Clutch drive assembly for the following. Replace clutch drive assembly if damaged, such as:
   a. Pinion gear turns roughly or turns in both directions.
   b. Pinion gear teeth broken or showing evidence of step wear.
   c. Deep scoring or other damage to shift lever collar.
5. Brush holder assembly for the following damage. Replace brush holder if damaged:
   a. Loose riveted joints.
   b. Cracked or broken insulation.
6. Brushes for excessive wear. Minimum allowable brush length is 12 mm (0.472 in.). Replace excessively worn brushes in sets.
7. Drive end housing bushing for scoring or other damage. Replace damaged bushing.
8. Ball bearings as follows:
   a. Hold armature or drive shaft and slowly rotate outer bearing race by hand.
   b. Check that bearing turns freely without binding or the feel of flat spots.
   c. Replace damaged bearings.

9. Armature assembly for the following:
   a. Gear teeth that are broken, or that show evidence of step wear or root interference.
   b. Rough commutator surface. Polish with No. 400 grit polishing cloth if necessary. Thoroughly clean metal dust from between commutator bars. If commutator surface cannot be repaired in this manner, replace armature assembly. **Do not turn commutator in a lathe.**
   c. Worn commutator. Replace armature assembly if commutator OD is less than 35 mm (1.378 in.) or if undercut depth at any point is less than 0.2 mm (0.008 in.). Do not undercut insulation.
10. Drive shaft for the following. Replace drive shaft if damaged:
   a. Scored or damaged shaft where it turns in bushing.
   b. Internal gear with teeth broken or showing evidence of step wear.
   c. Damaged spline. Clutch drive assembly must slide smoothly and easily over full length of splines.

Armature Tests

TEST FOR SHORTS

Check armature for shorts by placing on growler and holding hack saw blade over armature core while rotating armature. If saw blade vibrates, armature is shorted. After cleaning between commutator bars, recheck. If saw blade still vibrates, replace armature.

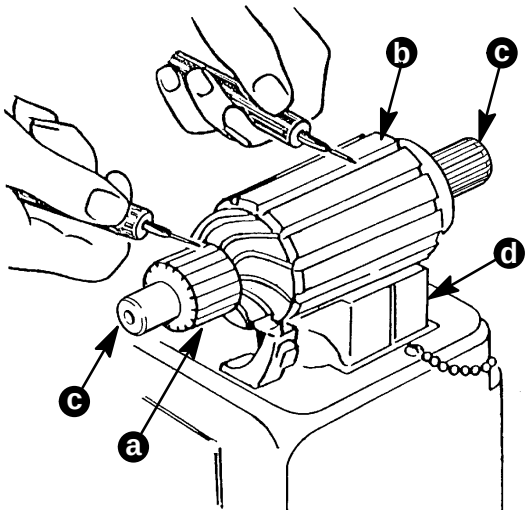


73233

a - Hacksaw Blade
b - Armature Core
c - Growler

TEST FOR GROUND

1. With continuity meter, place one lead on armature core or shaft and other lead on commutator.
2. If meter moves, armature is grounded and must be replaced.



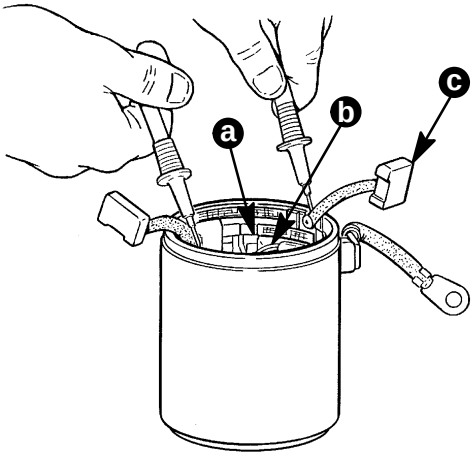
73234

a - Commutator
b - Armature Core
c - Shaft
d - Growler

Field Coil Tests

TEST FOR OPEN CIRCUIT

1. With continuity meter, place one lead on each end of field coils (insulated brush and field terminal connection).



73241

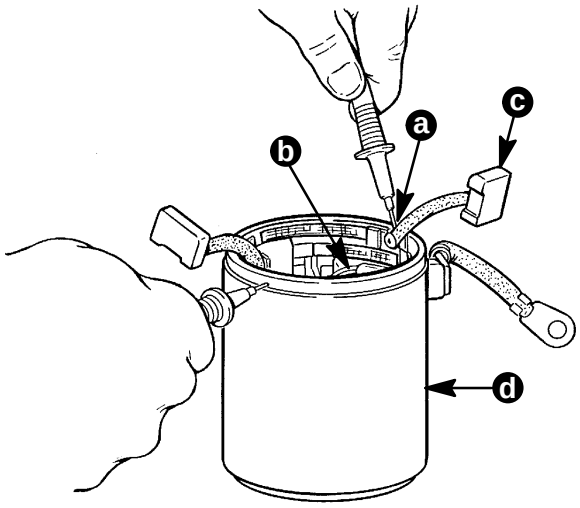
a - Field Coil
b - Field Terminal Connection
c - Brush

2. If meter does not move, field coils are open and must be replaced.

TEST FOR GROUND

IMPORTANT: Be sure that positive brushes and leads do not contact field frame assembly during test, or false reading will result.

1. With continuity meter, place one lead on field terminal connection and other lead to ground on field frame.



73242

a - Field Terminal Connection
b - Field Coil
c - Brush
d - Ground

2. If meter moves, field coils are grounded and must be replaced.

CLEANING THE COMMUTATOR

When inspection shows commutator roughness refer to “Cleaning and Inspection” for proper procedures.

LOOSE ELECTRICAL CONNECTIONS

If open soldered connection of armature to commutator leads is found during inspection, resolder with rosin flux.

IMPORTANT: Never use acid flux on electrical connections.

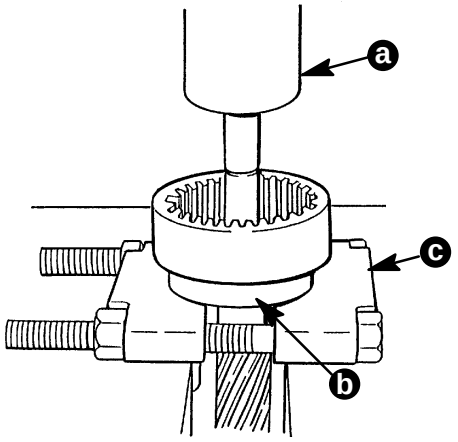
REASSEMBLY

After all parts are thoroughly tested and inspected and worn or damaged parts replaced, reassemble starter as follows:

1. Using a press, universal plate puller and driver, install a new drive shaft bearing, if bearing was removed.

⚠CAUTION

Ball bearings which are removed from drive shaft MUST BE replaced with new bearings. Removal procedure causes internal damage to bearings.

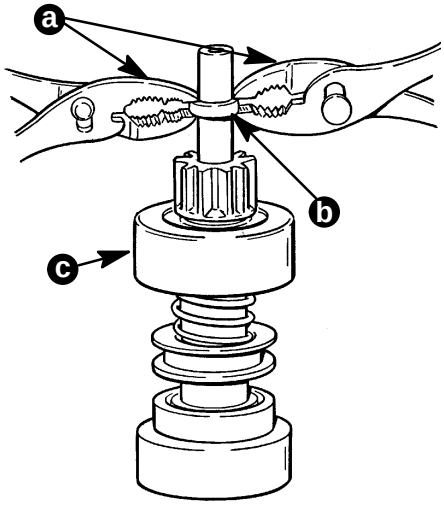


73243

a - Driver
b - Bearing
c - Universal Plate Puller

2. Install bearing housing plate and twist drive assembly onto drive shaft.

3. Use pliers to squeeze collar and retaining ring together.



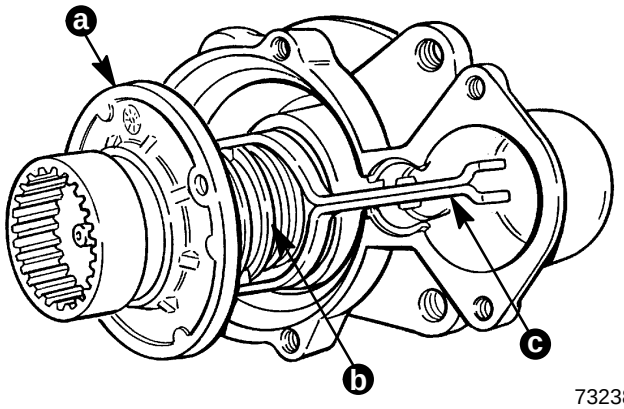
73244

a - Pliers
b - Retaining Ring and Collar
c - Drive Assembly

4. Using Delco Remy Lubricant No. 196094, lubricate the drive housing bushing (in drive housing), pivot hole and working surface on ends of shift lever, and the internal gear, shaft and spline on drive assembly.

5. Slide drive assembly and shift lever into drive housing. Align holes in drive shaft support with those in drive housing. Secure with fasteners and retainer.

NOTE: *Make sure that drive shaft support is fully seated in drive housing and that drive shaft bearing remains fully seated in drive shaft support.*

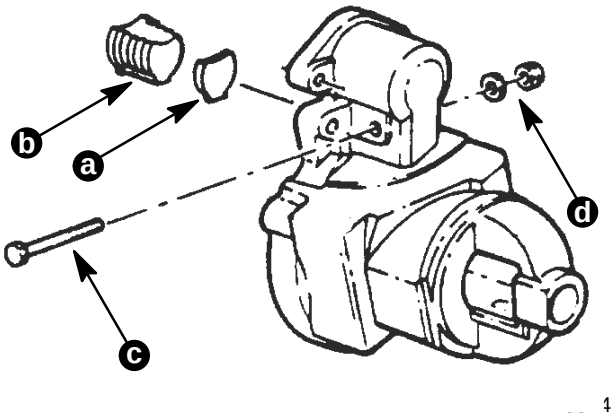


73238

a - Drive Shaft Support
b - Drive Assembly
c - Shift Lever

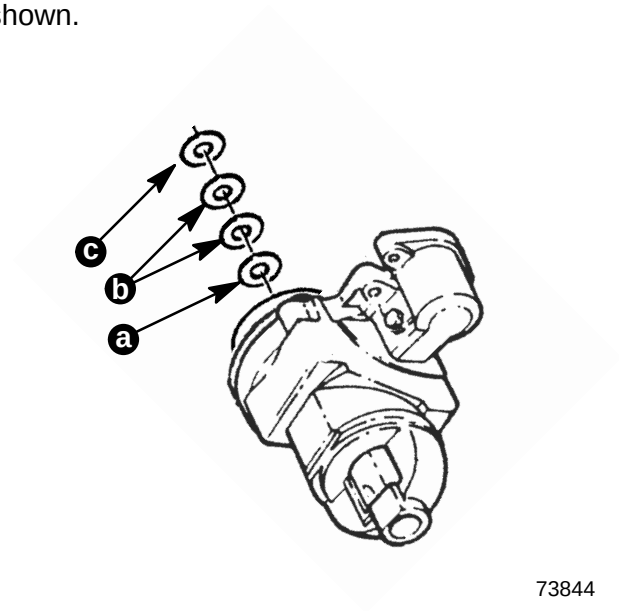
6. Install shift lever screw, washer and nut. Torque nut to 40 lb. in. (4.5 N·m).

7. Install small plate, if used , and housing plug into drive housing.



a - Plate (If Used)
b - Drive Housing Plug
c - Shift Lever Screw
d - Shift Lever Washer and Nut

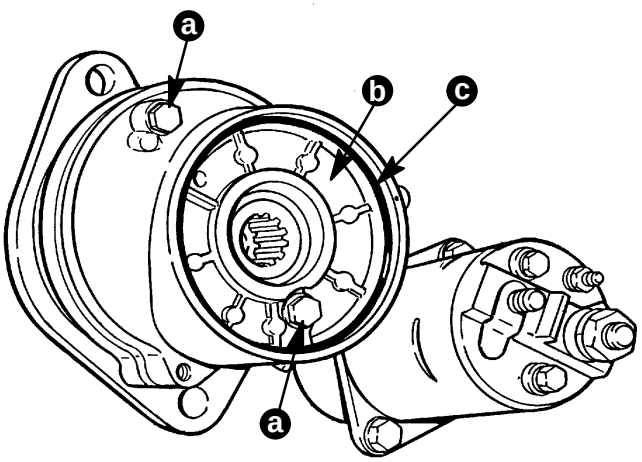
8. Install thick and thin washers *in same number and position* as noted during disassembly. Position the fiber washer on top of these washers as shown.



73844

a - Thick Washers
b - Thin Washers (One or Two May Be Used)
c - Fiber Washer

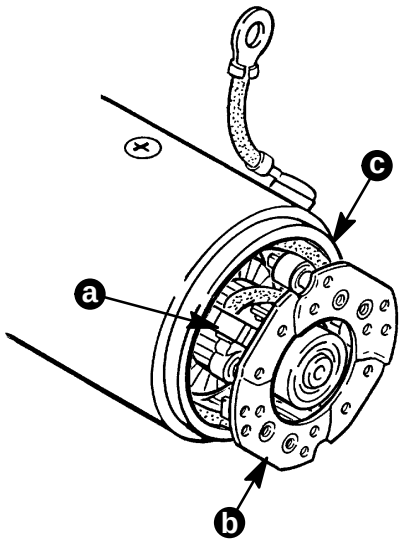
9. Install armature support bracket with rubber gasket in position. Secure with screws. Torque screws to 75 lb. in. (8.5 N·m).



73236

a - Screws
b - Armature Support Bracket
c - Rubber Gasket

10. Place dowel pin in hole in armature support bracket.
11. Align dowel pin to field frame and slide field frame and armature onto support bracket.
12. Position brush holder assembly with installed brushes over terminal end of frame and field. Attach terminals of insulated brush leads to conductors in frame and field assembly with insulated brush screws. Tighten screws to 13 lb. in. (1.5 N·m).
13. Twist brush springs away from brush holders, slide brushes in to contact commutator on armature and release brush springs to contact ends of brushes.



73245

a - Brush (2)
b - Brush Holder
c - Field Frame

14. Install commutator end frame as follows:

IMPORTANT: The commutator end frame O-ring can be easily easily damaged during installation of the end frame (cover). To prevent such damage, install the O-ring as described in the following steps.

a. Install the O-ring on field frame against the shoulder that will abut the end frame when installed.

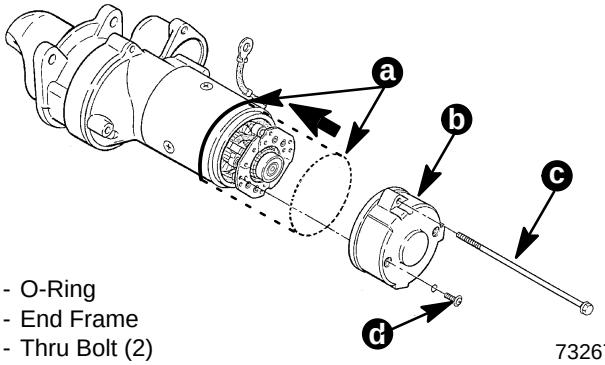
b. Carefully roll the O-ring out of this normal position onto the larger outer diameter of the field frame.

c. Place the end frame over the brush assembly leaving a gap just slightly larger than the thickness of the O-ring.

d. Align tapped holes in brush holder assembly with screw holes in end frame. Install the brush plate screws and torque to 25 lb. in. (2.8 N·m).

e. Install the thru bolts and tighten by hand but do not close the gap between the end frame and the field frame.

f. Then, roll the O-Ring back down into its installed position between the end frame and frame and field assembly.



73267

a - O-Ring
b - End Frame
c - Thru Bolt (2)
d - Brush Plate Screw (2)

15. Align the timing ribs on the edge of the frames to assure proper brush alignment.

NOTE: *These ribs (marks) are located in two places on the motor but will only match one way.*

16. Torque the thru bolts to 75 lb. in. (8.5 N·m).

17. Install solenoid as previously outlined.

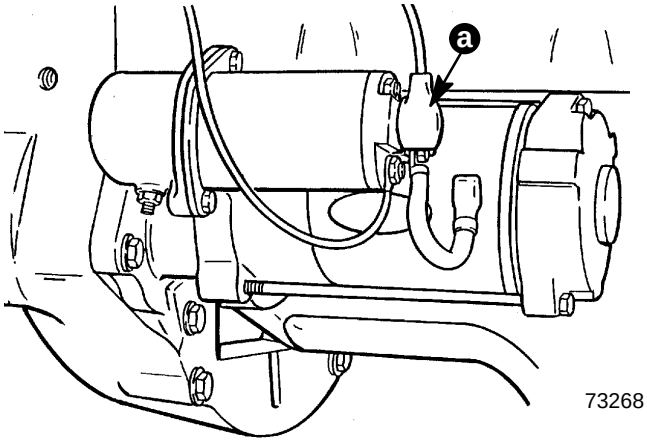
Clearances

PINION CLEARANCE

NOTE: *Internal clearances on the Delco Remy 28MT Series Starter are set by the factory. During service always install the same number of washers as found during disassembly. Refer to "Exploded Views".*

Installation

1. Place starter motor and solenoid assembly in position and install mounting bolts. Torque bolts to 50 lb. ft. (68 N·m).
2. Fasten wires as outlined in wiring diagram.
3. Coat solenoid terminal connections with Quicksilver Liquid Neoprene.
4. Place rubber boot over positive battery cable connection.



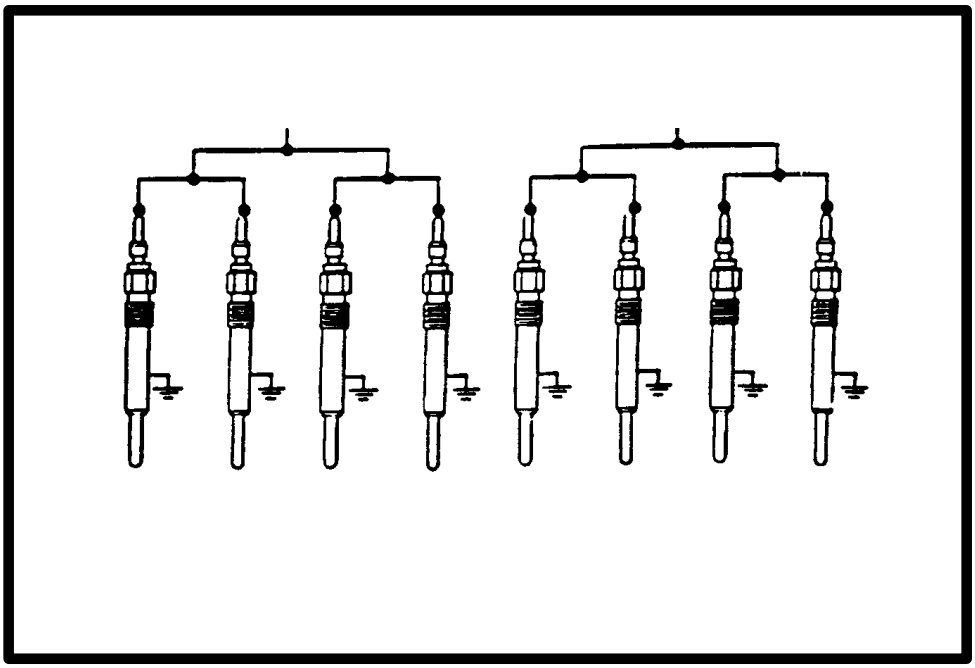
73268

a - Rubber Boot

ELECTRICAL SYSTEMS

4

B



GLOW PLUG SYSTEM

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Glow Plug Controller System	4B-2
Glow Plug Circuit Diagram	4B-2
Special Tools	4B-3
Flash Codes	4B-3
Glow Plug System	4B-3
Glow Plug Relay	4B-4
Removal	4B-4
Inspection and Cleaning	4B-4
Installation	4B-4

Specifications

Glow Plugs

Location	Cylinder Head
Quantity	8

Glow Plug Controller System

The purpose of the glow plug system is to warm–up the engine cylinders to improve / enhance cold engine starting and to reduce exhaust emissions during engine warm–up.

The Electronic Controle Module (ECM) is programmed to turn the “WAIT” to start light on and energize the glow plugs (via the glow plug relay) each time the ignition switch is place in the “ON” position prior to starting an engine.

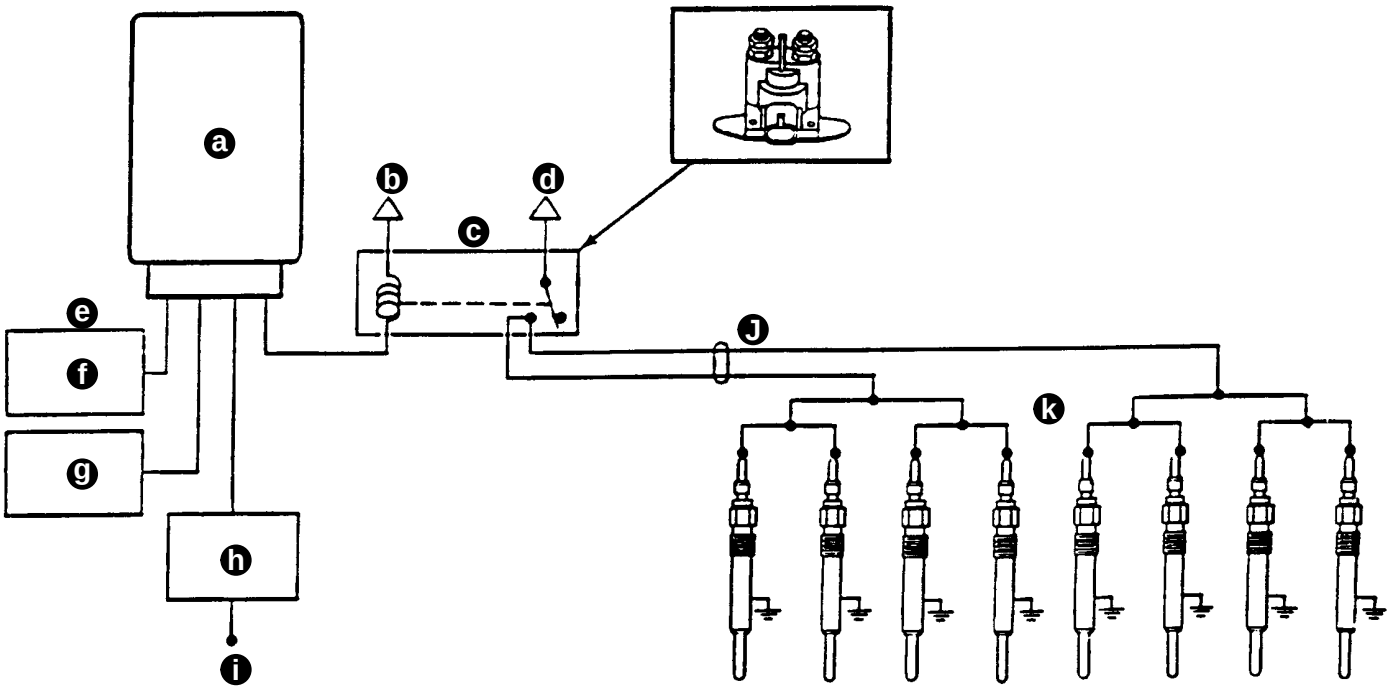
The ECM monitors battery voltage and uses information from the engine oil temperature (EOT) and barometric (BARO) sensors to determine the amount of “WAIT” to start light “ON” time and glow plug activation time. The ECM controls the “WAIT” to start light and the activation of the glow plugs separately.

The glow plugs are activated for a longer period of time, if the engine is cold or the barometric pressure is low (high altitude). Battery voltage is monitored to extend glow plug life. If the battery voltage is high, power to the glow plugs is modulated by turning the glow plug relay ON/OFF at programmed intervals.

The engine is ready to start when “WAIT” light is extinguished by the ECM. The glow plugs may remain “ON” for up to 120 seconds while the engine is running to reduce exhaust emissions during engine warm–up.

Glow Plug Circuit Diagram

a - ECM
b - Switched Igniton
c - Glow Plug Relay
d - + VBAT
e - Inputs
f - Barometric Pressure Sensor Baro.
g - Engine Coolant Sensor ECT
h - Wait Lamp
i - + VBAT
j - Part of Engine Harness
k - Glow Plug harness



Special Tools

Glow Plug/Injector “T” Harness . . . . . ZTSE 4345

Flash Codes

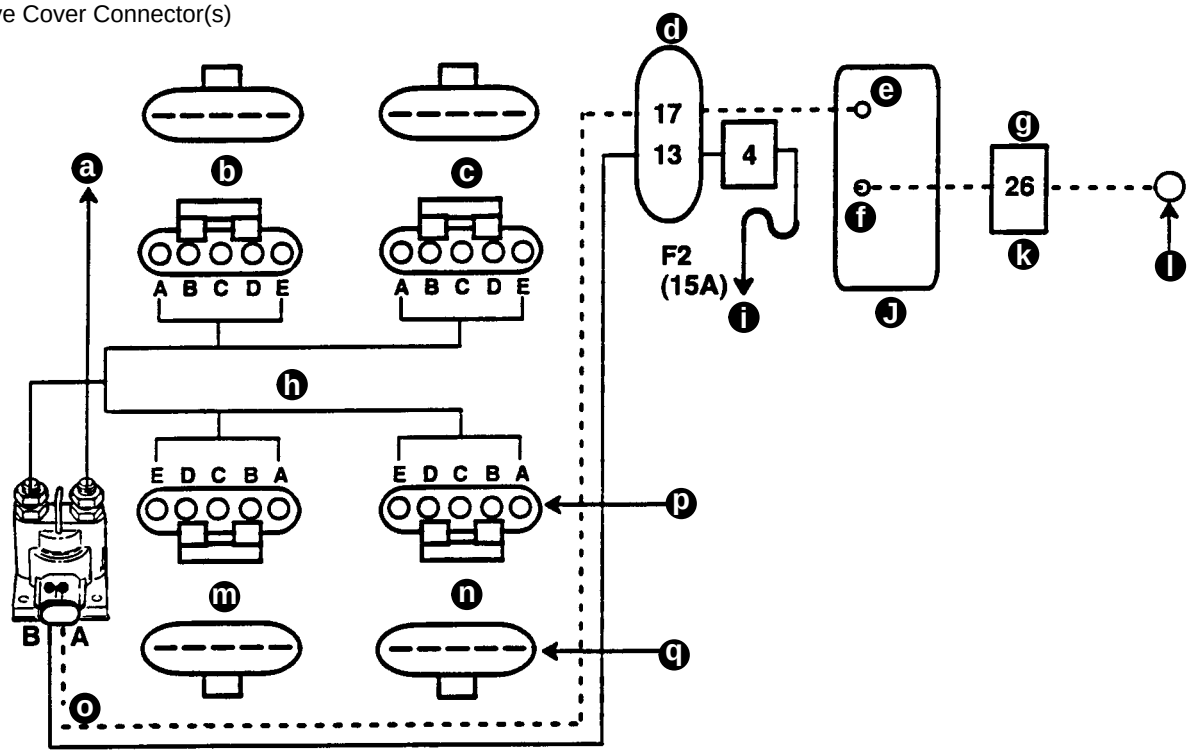
251	Glow Plug Continuity OCC Self Test fault
252	Glow Plug Lamp OCC Self Test fault

Glow Plug System

⚠CAUTION

DO NOT PERFORM VOLTAGE CHECKS WITH THE ENGINE RUNNING.
Injector solenoid operating voltage 115 V DC. @ 10 Amps present on injector curcuits.

a - B+ Starter Solenoid (Fusible Link)
b - (a) (b) (c) (d) (e) Cyl. 1 & 3
c - (a) (b) (c) (d) (e) Cyl. 5 & 7
d - Deutsch Connector (On Valve Cover)
e - Pin #58
f - Pin #13
g - Deutsch Connector (On Cowl)
h - Glow Plug Feed
i - Keypwr
j - ECM Connector
k - Glow Plug Lamp (Control)
l - Keypwr
m - (e) (d) (c) (b) (a) Cyl. 2 & 4
n - (e) (d) (c) (b) (a) Cyl. 6 & 8
o - Glow Plug (ECM) Control
p - Engine Harness Connector
q - Valve Cover Connector(s)



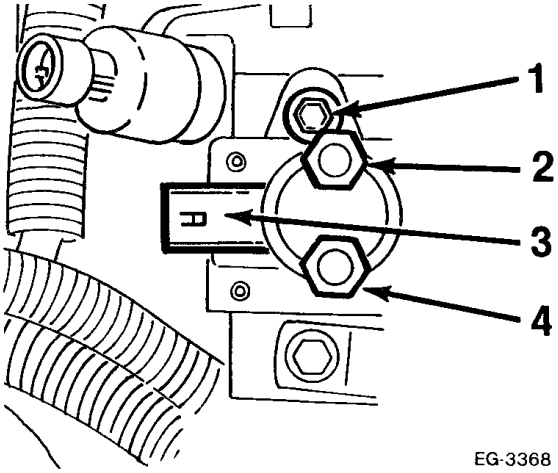
Glow Plug Relay

SEE DIAGNOSTIC SECTION FOR DETAILS ON GLOW PLUG SYSTEM TROUBLESHOOTING.

Removal

IMPORTANT: Do not use a screwdriver or similar tool to pry-off terminal cover due to presence of battery voltage at the relay terminals.

1. Disconnect batteries.
2. Remove glow plug relay plastic terminal cover and pull off.
3. Disconnect 12V power wire, glow plug wire and relay control harness connector.
4. Remove two (2) mounting screws and lift relay from engine.



1 - Glow Plug Relay Mounting Bolt (2)
2 - Glow Plug Relay Connector
3 - Relay Control Harness Conn.
4 - Battery Terminal Connector

Inspection and Cleaning

1. Inspect base and relay housing for cracks.

IMPORTANT: The glow plug relay is not repairable beyond being certain that all electrical connections to it are clean and tight. refer to engine diagnostic manual for glow plug system trouble shooting.

Installation

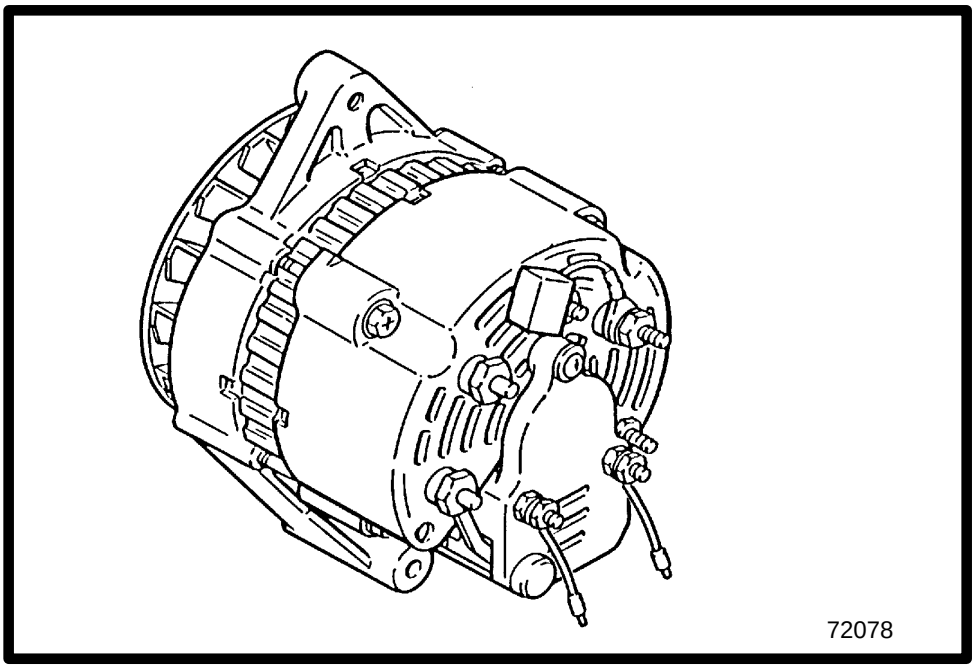
1. Install glow plug relay onto its bracket and tighten two (2) mounting screws.
2. Install glow plug wire and 12V power wire to top of relay. Connect relay control harness connector Tighten terminal nuts.
3. Snap glow plug relay cover into place.
4. Reconnect batteries.

NOTE: *Refer to Section 3A "Cylinder Head and Valves" for glow plug and Under Valve Cover (UVC) connections.*

ELECTRICAL SYSTEMS

4

C



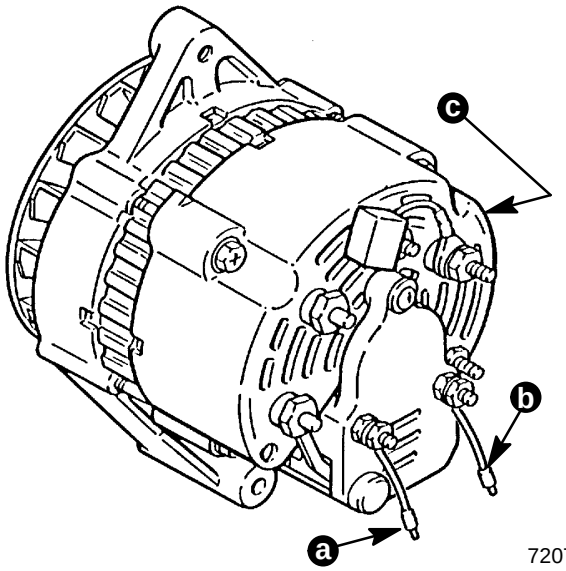
CHARGING SYSTEM

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Identification



72078

a - Excitation Wire - PURPLE
b - Sensing Wire - RED/PURPLE)
c - Mando Part Number (Hidden in This View

Mando 65 Amp Alternator

Mando 65 Amp Alternator

Replacement Parts Warning

⚠ WARNING

Electrical, ignition and fuel system components on your MerCruiser are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.

Use of replacement electrical, ignition or fuel system components, which do not comply with these rules and regulations, could result in a fire or explosion hazard and should be avoided.

Specifications

Description	Specification
Excitation Circuit	1.3 to 2.5 Volts
Current Output	60 Amp. Min.
Voltage Output	13.9 to 14.7 Volts
Condenser Capacity	.5 MFD
Min. Brush Length	1/4 in. (6 mm)

Tools/Sealants

NOTE: *Depress belt with thumb at midway point between circulating pump pulley and alternator.*

Part Number	Description
91-76032	Magneto Analyzer
91-31229A5	Bearing Removal and Installation Kit
91-37241	Universal Puller Plate
91-99750	Multi-Meter/DVA Tester
92-25711	Quicksilver Liquid Neoprene
Obtain Locally	Ammeter (0-80 Amps)

Torque Specifications

Fastener Location	Lb. Ft. (N•m)	Lb. In. (N•m)
End Frame Screws		50-60 (6-7)
Brush Setscrews		16-20 (1-2)
Regulator Mounting Screws		40-45 (4-5)
Regulator Leads		20-30 (2-3)
Ground Terminal Nut		20-30 (2-3)
Pulley Nut	35-50 (48-68)	
Alternator Brace to Alternator		192 (28)
Alternator Brace to Block	30 (41)	
Alternator to Mounting Bracket	35 (48)	
Alternator Mounting Bracket	30 (41)	
Alternator Support Bracket	Tighten Securely	
V-Belt Tension (Note)	Depress 3/16 In. (5 mm)	

NOTE: *Depress belt with thumb at midway point between circulating pump pulley and alternator.*

Description

The alternator has a rotor, which is supported in two end frames by ball bearings, and is driven by a pulley at approximately twice engine speed. The rotor contains a field winding that is enclosed between two multiple-finger pole pieces. The ends of the field winding are connected to two brushes (mounted in the rear end frame) which make continuous sliding (or slipping) contact with the slip rings. The current (flowing through the field winding) creates a magnetic field that causes the adjacent fingers of the pole pieces to become alternate north and south magnetic poles.

A 3-phase stator is mounted directly over the rotor pole pieces and between two end frames. It consists of three windings wound 120 degrees electrically out-of-phase on the inside of a laminated core. The windings are all connected together on one end, while the other ends are connected to a full-wave rectifier bridge.

The rectifier bridge contains six diodes which are arranged so that current flows from ground, through the stator and to the output terminal, but not in the opposite direction.

When current is supplied to the rotor field winding, and the rotor is turned, the movement of the magnetic fields created induces an alternating current into the stator windings. The rectifier bridge then changes this alternating current to direct current which appears at the output terminal. A diode trio also is connected to the stator windings to supply current to the regulator and the rotor field during operation.

Voltage output of the alternator is controlled by regulating the current supplied to the rotor field. This is accomplished by a transistorized voltage regulator that senses the voltage at the battery and regulates the field current to maintain alternator voltage within prescribed limits for properly charging the battery. Current output of the alternator does not require regulation, as maximum current output is self-limited by the design of the alternator. As long as the voltage is regulated within the prescribed limits, the alternator cannot produce excessive current. A cut-out relay in the voltage regulator also is not required, as the rectifier diodes (which allow current to flow in one direction only) prevent the battery from discharging back through the stator.

Due to the lack of residual magnetism in the rotor pole pieces, a small amount of current must be supplied to the rotor field to initially start the alternator charging. This is accomplished by means of an excitation circuit in the regulator which is connected to the ignition switch. Once the alternator begins to produce output, field current is supplied solely by the diode trio, as explained, preceding.

The alternator also is equipped with a fan (mounted on the rotor shaft) which induces air flow through the alternator to remove the heat created by the rectifiers and stator. A capacitor protects the rectifier system from high voltages and suppresses radio noise.

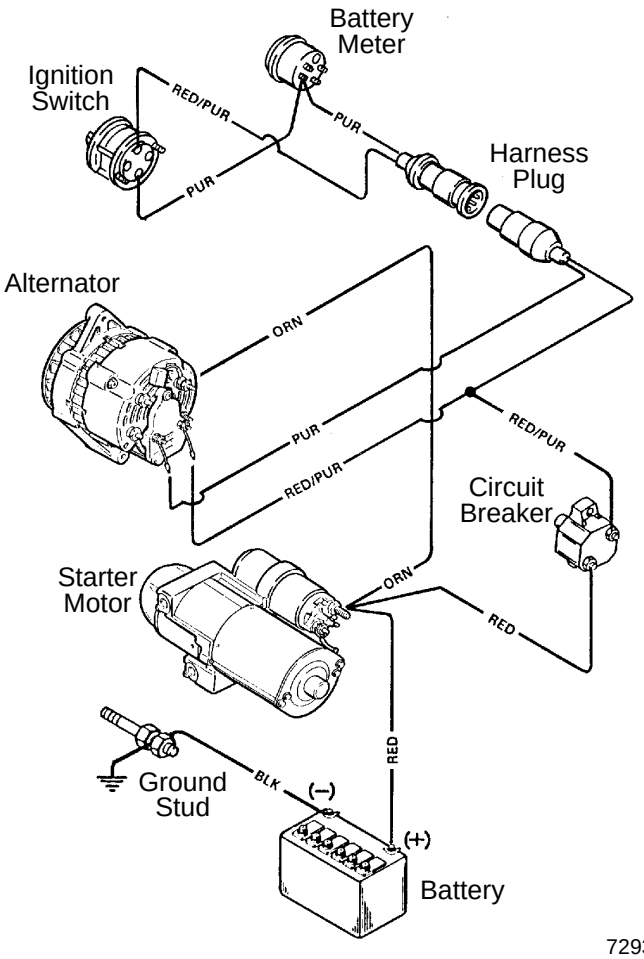
Precautions

The following precautions MUST BE observed when working on the alternator system. Failure to observe these precautions may result in serious damage to the alternator or alternator system.

1. DO NOT attempt to polarize the alternator.
2. DO NOT short across or ground any of the terminals on the alternator, except as specifically instructed in the “Troubleshooting Tests”.
3. NEVER disconnect the alternator output lead or battery cables when the alternator is being driven by the engine.
4. NEVER disconnect regulator lead from alternator regulator terminal when the alternator is being driven by the engine.
5. ALWAYS remove negative (-) battery cable from battery before working on alternator system.
6. When installing battery, BE SURE to connect the positive (+) battery cable to the positive (+) battery terminal and the negative (-) (grounded) battery cable to negative (-) battery terminal.
7. If a charger or booster battery is to be used, BE SURE to connect it in parallel with existing battery (positive to positive; negative to negative).

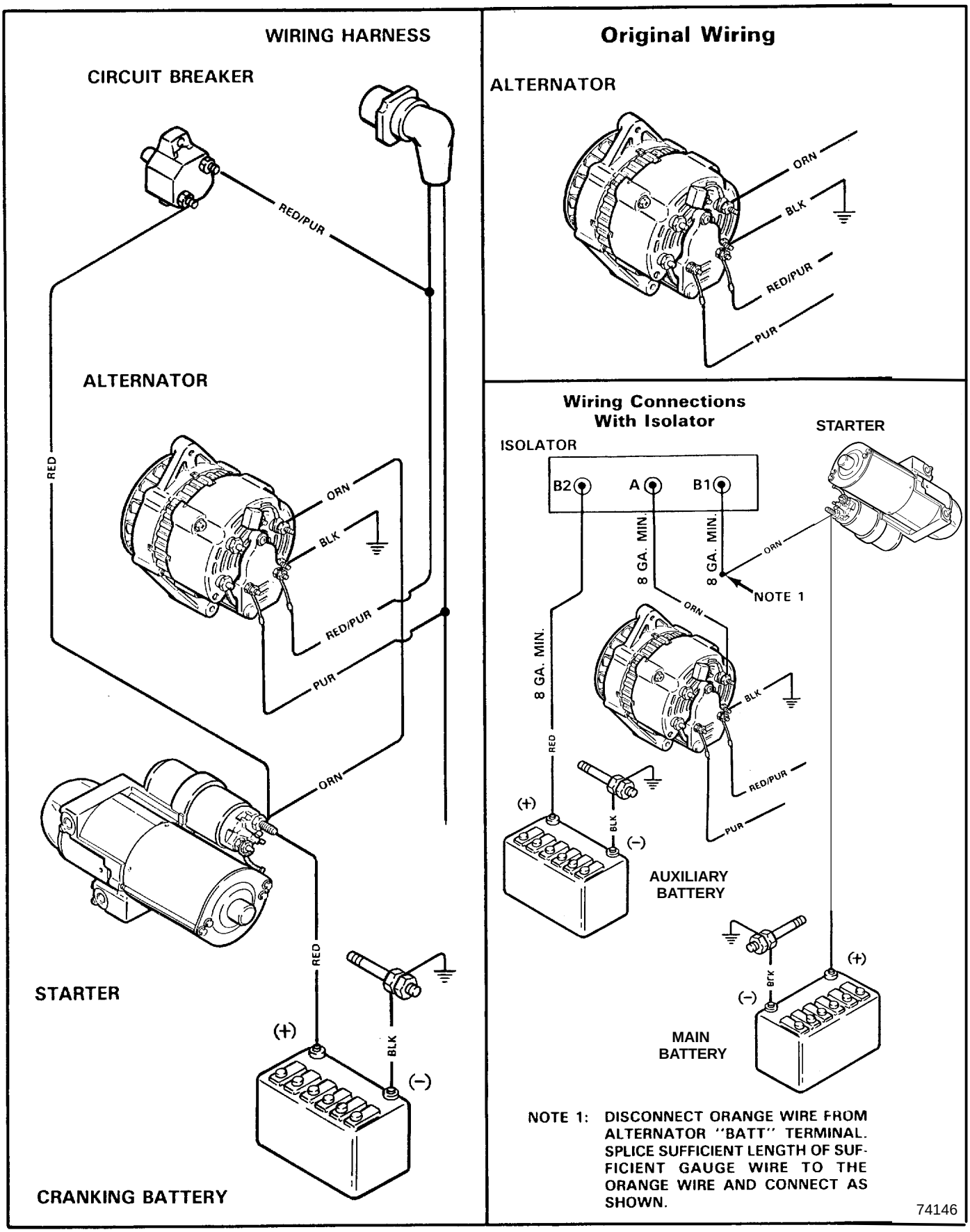
System Components

The alternator system consists of the alternator, battery, the ignition switch and the wiring which connects these components.



72933

Alternator Circuits - Typical



Battery Isolators

Dual Battery Charging Systems Using a Battery Isolator

Battery isolators allow the addition of an auxiliary (second) battery to the MerCruiser electrical system. The auxiliary battery is primarily used as a power source for various accessories installed on the boat. The battery isolator will allow the alternator to charge both the cranking and auxiliary batteries at the same time while preventing accessories, connected to the auxiliary battery, from drawing power from the cranking battery.

Mercury Marine does not manufacture any battery isolator systems. Battery isolators must be bought from an outside manufacturer. Mercury Marine suggests following the manufacturer's instructions carefully.

IMPORTANT: Alternators used on MerCruiser engines ARE NOT equipped with an isolation diode.

⚠ CAUTION

Follow battery isolator manufacturer's instructions for wire gauge. Battery isolator installation must conform to BIA Low Voltage Wiring Standard No. 125-79.

NOTE: *MerCruiser engines equipped with a 3-wire, belt driven alternator, can use a battery isolator.*

WIRING COLOR CODE ABBREVIATIONS

BLK	=	BLACK
BLU	=	BLUE
BRN	=	BROWN
GRY	=	GRAY
GRN	=	GREEN
ORN	=	ORANGE
PNK	=	PINK
PUR or PPL	=	PURPLE
RED	=	RED
TAN	=	TAN
WHT	=	WHITE
YEL	=	YELLOW
LIT or LT	=	LIGHT
DRK	=	DARK

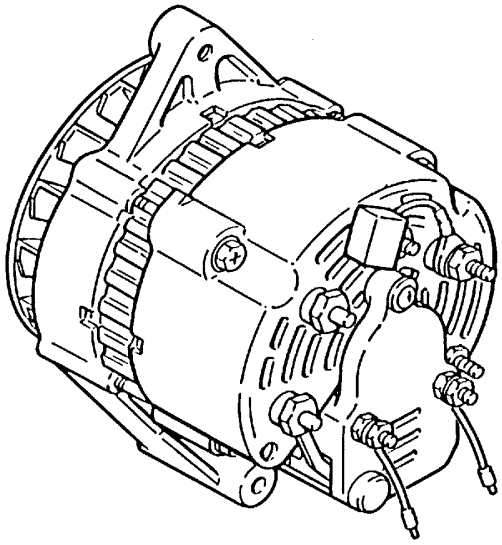
Periodic Maintenance

The following maintenance check should be performed every 50 hours or 60 days (whichever comes first) in fresh water areas or every 25 hours or 30 days in salt water areas.

⚠ CAUTION

Remove all battery cables from battery (before conducting the following check) to prevent accidentally shorting out electrical system.

1. Inspect entire alternator system for corroded or loose connectors.
2. Check wiring for frayed or worn insulation.
3. Check alternator drive belt for excessive wear, cracks, fraying and glazed surfaces. Also, check drive belt tension and adjust, if necessary, as explained under "Drive Belt Tension Adjustment".
4. Check alternator mounting bolts for adequate tightness.
5. Inspect slip ring end frame flame arrestor screen for debris and clean, if necessary, using compressed air or a cloth. Screen MUST BE clean, or alternator may overheat.

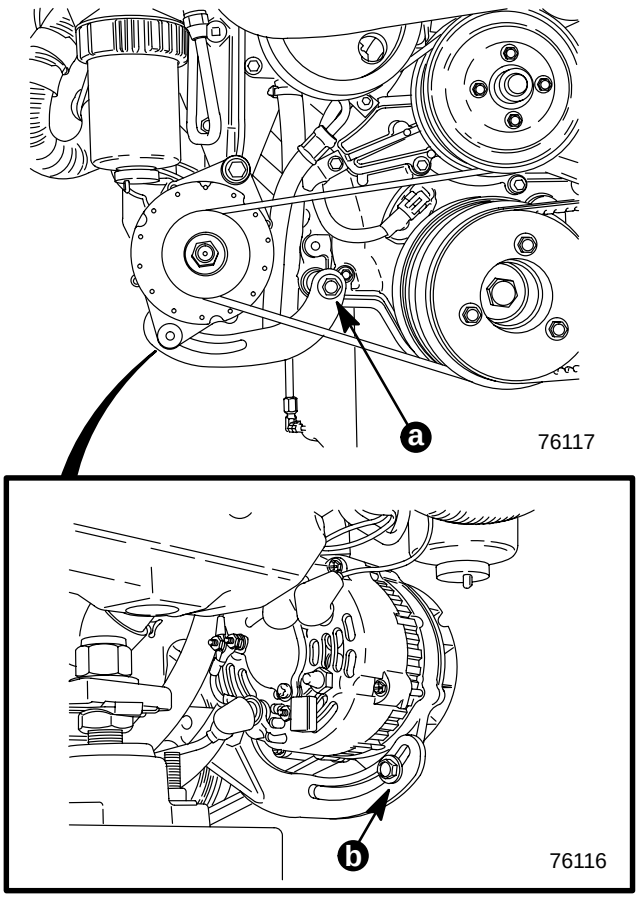


72078

Drive Belt Tension Adjustment

Alternator

1. Install drive belt on pulleys and adjust tension as follows:
   a. Pivot alternator away from engine, as required, until correct tension is obtained as shown. Belt should depress 3/16 in. (5 mm).



a - Alternator Mounting Hardware
b - Alternator Tensioning Bolt (Hidden in This View)

   b. After obtaining correct tension, securely retighten alternator brace attaching bolts and alternator mounting bolts.
2. If a new drive belt has been installed, recheck belt tension after running for five minutes.

Troubleshooting Tests (Alternator on Engine)

Use the following tests in conjunction with the “Troubleshooting” in Section 1. Before proceeding with the tests, however, perform the following checks to eliminate possible problem areas. Also observe “Precautions,” preceding, to prevent damage to alternator system.

1. If problem is an undercharged battery, check to ensure that undercharged condition has not been caused by excessive accessory current draw or by accessories which have accidentally been left on. Also, check that undercharged condition has not been caused by running engine at too low a speed for extended periods of time.
2. Check physical condition and state of charge of battery, as outlined in “Battery - Storage” in Section 4A. Battery MUST BE at least 75% (1.230 specific gravity) of fully charged to obtain valid results in the following tests. If not, charge battery before testing system.
3. Inspect entire alternator system wiring for defects. Check all connections for tightness and cleanliness, particularly battery cable clamps and battery terminals.
4. Check alternator drive belt for excessive wear, cracks, fraying and glazed surfaces and replace if necessary. Also, check drive belt tension and adjust if necessary, as outlined under “Drive Belt Tension Adjustment”.

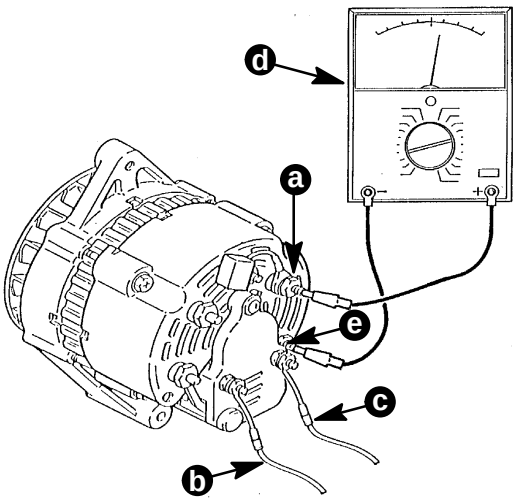
Circuitry Test

Perform the following tests, using a 0-20 volt DC voltmeter, to check that all of the circuits between the alternator and the other components within the alternator system are in good condition.

OUTPUT CIRCUIT

1. Connect positive (+) voltmeter lead to alternator output terminal and negative (-) lead to a ground terminal on alternator.

2. Wiggle engine wiring harness while observing voltmeter. Meter should indicate approximate battery voltage and should not vary. If no reading is obtained, or if reading varies, check alternator output circuit for loose or dirty connections or damaged wiring.

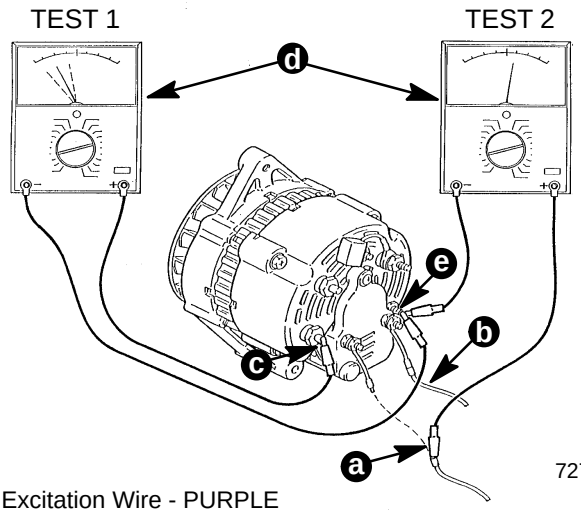


72784

a - Output Wire - ORANGE
b - Excitation Wire - PURPLE
c - Sensing Wire - RED/PURPLE
d - Voltmeter (0-20 Volts)
e - Ground

EXCITATION CIRCUIT

1. Connect positive (+) voltmeter lead to tie strap/terminal on alternator and negative (-) lead to a ground terminal on alternator (Test 1).
2. Turn ignition switch to “RUN” position and note voltmeter reading. Reading should be 1.3 to 2.5 volts.
3. If no reading is obtained, an opening exists in alternator excitation lead or in excitation circuit of regulator. Unplug PURPLE lead from regulator. Connect positive voltmeter lead to purple lead and negative voltmeter leads to ground (Test 2). If voltmeter now indicates approximate battery voltage, voltage regulator is defective and must be replaced. If no voltage is indicated, check excitation circuit for loose or dirty connections or damaged wiring.
4. If reading is between .75 and 1.1 volts, rotor field circuit probably is shorted or grounded. Disassemble alternator and test rotor as outlined under “Alternator Repair,” following.
5. If reading is between 6.0 and 7.0 volts, rotor field circuit probably is open. Remove regulator and inspect for worn brushes or dirty slip rings. Replace brushes if less than 1/4 in. (6 mm) long. If brushes and slip rings are in good condition, disassemble and perform rotor test as outlined under “Component Testing - Rotor” following.



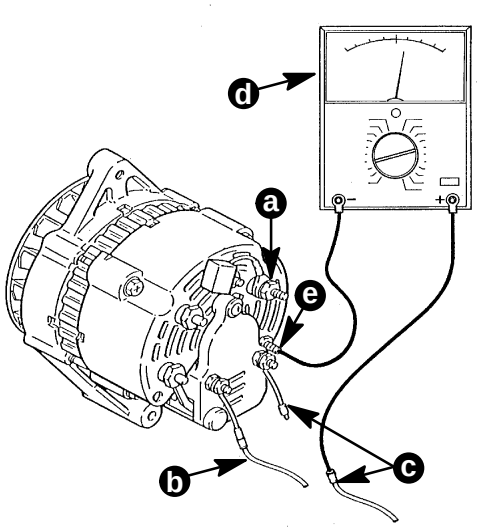
72785

a - Excitation Wire - PURPLE
b - Sensing Wire - RED/PURPLE
c - Tie Strap/Terminal
d - Voltmeter (0-20 Volts)
e - Ground

SENSING CIRCUIT

1. Unplug red/purple lead from voltage regulator.
2. Connect positive (+) voltmeter lead to RED/PURPLE lead and negative (-) voltmeter lead to ground terminal.

3. Voltmeter should indicate battery voltage. If battery voltage is not present, check sensing circuit (RED/PURPLE lead) for loose or dirty connection or damaged wiring.



72786

a - Output Wire - ORANGE
b - Excitation Wire - PURPLE
c - Sensing Wire - RED/PURPLE
d - Voltmeter (0-20 Volts)
e - Ground

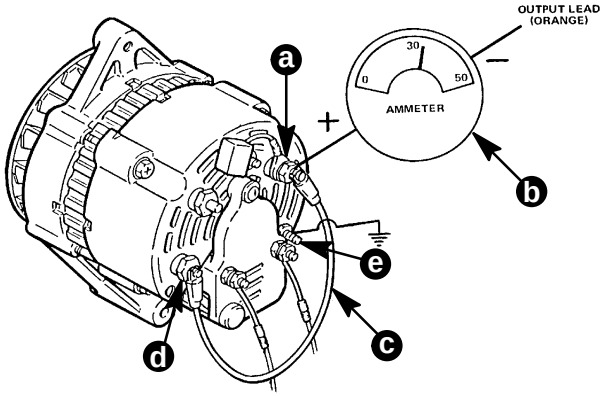
Current Output Test

Perform this test to check if alternator is capable of producing rated current output, using a 0-80 amp DC ammeter.

⚠WARNING

Be sure that engine compartment is well-ventilated and that there are no gasoline vapors present (during the test) to prevent the possibility of an explosion and/or a fire, should a spark occur.

1. Disconnect negative (-) battery cable from battery.
2. Disconnect ORANGE lead from alternator output terminal and connect ammeter in series between lead and output terminal. Connect positive (+) side of ammeter toward output terminal.
3. Reconnect negative battery cable.
4. Turn on all accessories and turn ignition switch to “RUN” position, and allow glow plug system to operate through one cycle. Turn switch to “OFF” position. Turn off accessories.
5. Start engine and adjust engine speed to 1500-2000 RPM. Quickly observe ammeter. Reading should be at least 30 amps.
6. If reading is low, stop engine and connect a jumper wire between alternator output terminal and regulator terminal. Repeat Steps 4 and 5.
7. If reading is now within specifications, diodes are faulty. Disassemble alternator and replace rectifier as explained under “Alternator Repair,” following, to determine if fault is in regulator or alternator.
8. If reading is still low with jumper wire connected, perform “Voltage Output Test,” following, to determine if fault is in regulator or alternator.



72787

a - Output Wire - ORANGE
b - Ammeter (0-80 Amps)
c - Jumper Lead
d - Regulator Terminal
e - Ground

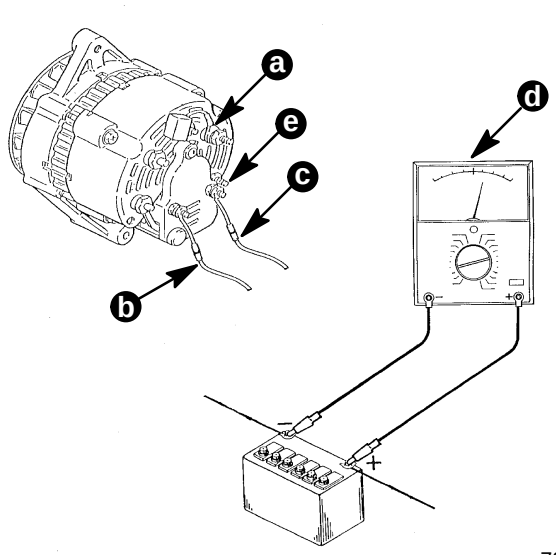
Voltage Output Test

Perform this test to determine if voltage regulator is operating correctly, using a 0-20 volt DC voltmeter.

IMPORTANT: Battery MUST BE fully charged (1.260 or above specific gravity) to obtain proper voltage reading in this test. If necessary, charge battery with a battery charger or allow engine to run a sufficient length of time to fully charge battery before taking reading.

1. Connect positive (+) voltmeter lead to positive battery terminal and negative (-) voltmeter lead to negative terminal.
2. Start engine and run at fast idle until engine reaches normal operating temperature. Adjust engine speed to 1500-2000 RPM and observe voltmeter for highest reading. Reading should be between 13.9 and 14.7 volts.

3. If reading is high, check for a loose or dirty regulator ground lead connection. If connection is good (and sensing circuit checked out good in “Circuitry Test”), voltage regulator is faulty and must be replaced. Be sure to disconnect battery cables before attempting to remove regulator.



a - Output Wire - ORANGE
b - Excitation Wire - PURPLE
c - Sensing Wire - RED/PURPLE
d - Voltmeter (0-20 Volts)
e - Ground

⚠ WARNING

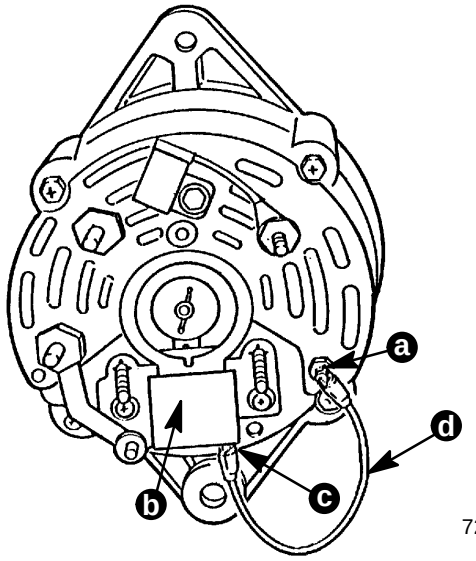
Be sure that engine compartment is well-ventilated and that there are no gasoline vapors present (during the next steps) to prevent the possibility of an explosion and/or fire, should a spark occur.

⚠ CAUTION

DO NOT allow tie jumper wire to contact alternator end frame (in next step), as rectifier and diode assembly may be damaged.

4. Remove four nuts holding excitation and sensing wires and Phillips screw. Remove regulator cover and install wires and nuts for testing. Connect a jumper wire from the ground stud to the brush terminal on the lower right- hand side of the brush assembly. Restart engine and gradually increase engine speed to 1500 RPM while observing voltmeter. DO NOT allow voltage to exceed 16 volts.

5. If a voltmeter reading of 14.5 volts or above is now obtained, voltage regulator is faulty and must be replaced. If voltmeter reading is below 14.5 volts, inspect brushes and slip rings for wear, dirt or damage. If brushes and slip rings are good, alternator is faulty internally. Disassemble alternator and test components, as outlined under “Alternator Repair,” following.



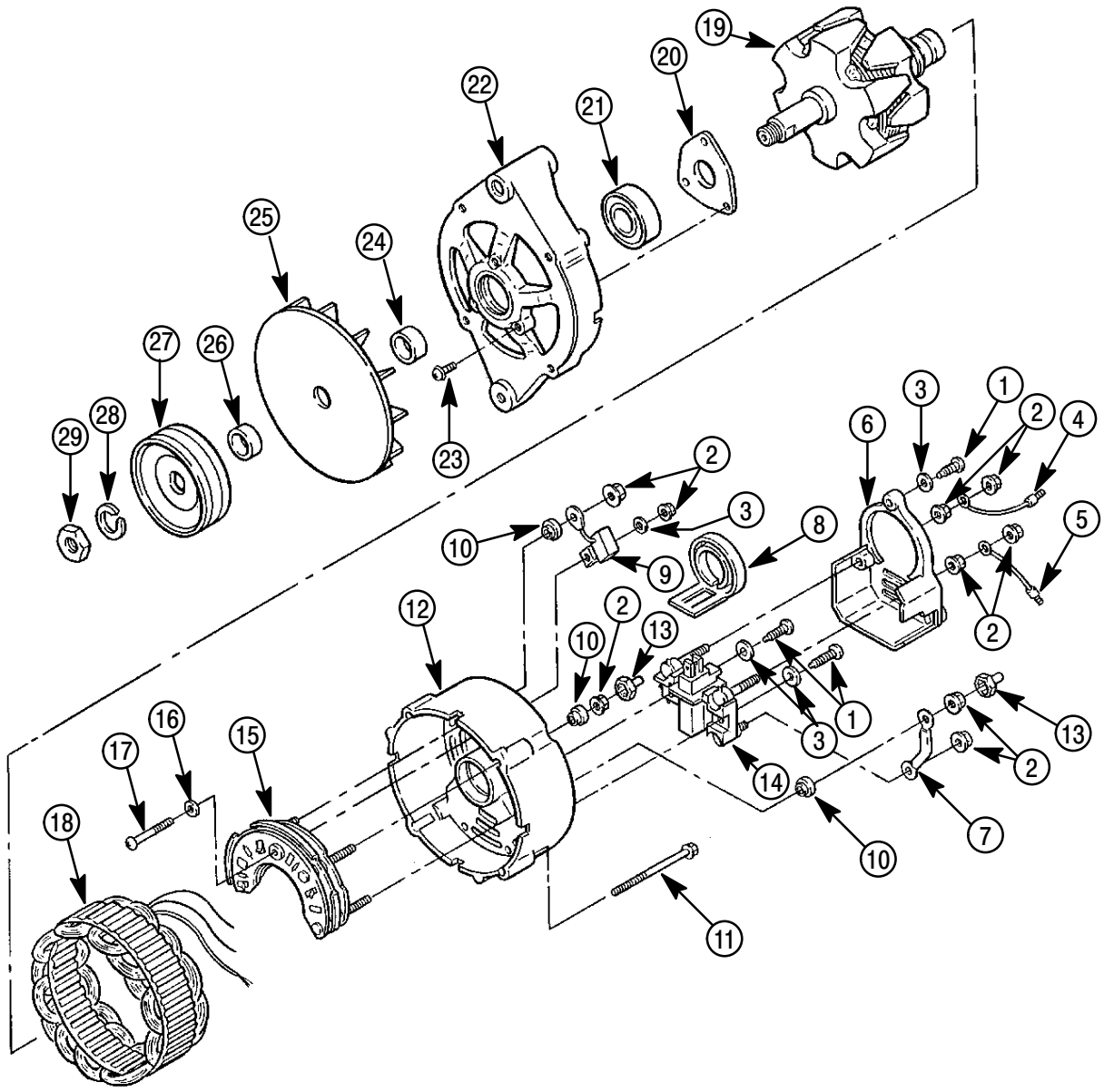
a - Ground
b - Brush/Regulator Assembly
c - Brush Terminal
d - Jumper Wire (Solder Connection to Ground)

Alternator Repair

Removal

1. Disconnect negative (-) battery cable from battery.
2. Disconnect wiring harness from alternator.
3. Loosen alternator support bracket screw.
4. Loosen alternator brace-to-alternator and alternator brace-to-engine attaching screws. Loosen alternator mounting bolt, then pivot alternator inward and remove alternator drive belt.
5. Remove alternator brace-to-alternator attaching bolt and washer.
6. Remove alternator mounting bolt, washers, and nut. Remove alternator.

Exploded View



72276

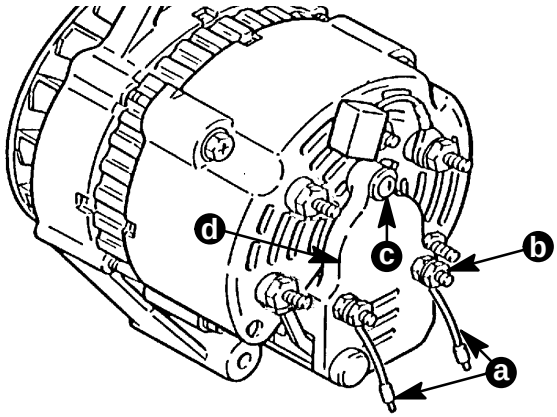
1 - Screw (3)
2 - Nut (9)
3 - Flat Washer (4)
4 - Sensing Wire (RED/PURPLE)
5 - Excitation Wire (PURPLE)
6 - Cover
7 - Tie Strap
8 - Rubber Gasket
9 - Condenser
10- Insulator (3)
11- Bolt (4)
12- End Frame (Rear)
13- Cap (2)
14- Brush/Regulator Assembly
15- Rectifier Assembly
16- Flat Washer
17- Screw
18- Stator
19- Rotor and Slip Rings
20- Retaining Plate
21- Front Bearing
22- End Frame (Front)
23- Screw (3)
24- Fan Spacer
25- Fan
26- Pulley Spacer
27- Pulley
28- Lockwasher
29- Nut

Mando 65 Amp Alternator

Disassembly

IMPORTANT: The following instructions are for complete disassembly and overhaul of the alternator. In many cases, however, complete disassembly of alternator is not required and, in those cases, it is necessary only to perform the operations required to repair or replace the faulty part.

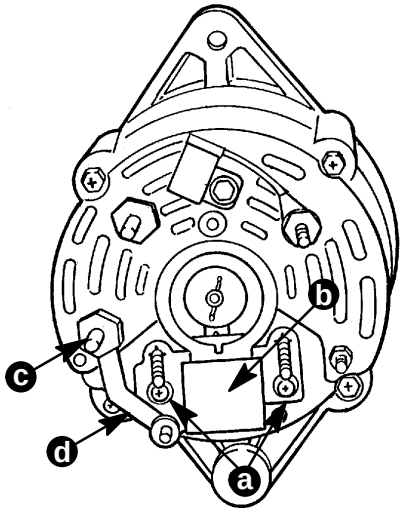
1. Mount alternator in a vise so that rear end frame is facing you.
2. Disconnect regulator leads from terminals on rear end frame. Remove four nuts, Phillips head screw and two regulator leads. Then pull regulator cover away from rear end frame.



72963

a - Regulator Leads
b - Nuts (4)
c - Phillips Head Screw
d - Regulator Cover

3. Remove stud cover insulator, two nuts and tie strap from brush/regulator assembly.
4. Remove two brush/regulator attaching screws and remove brush/regulator assembly.



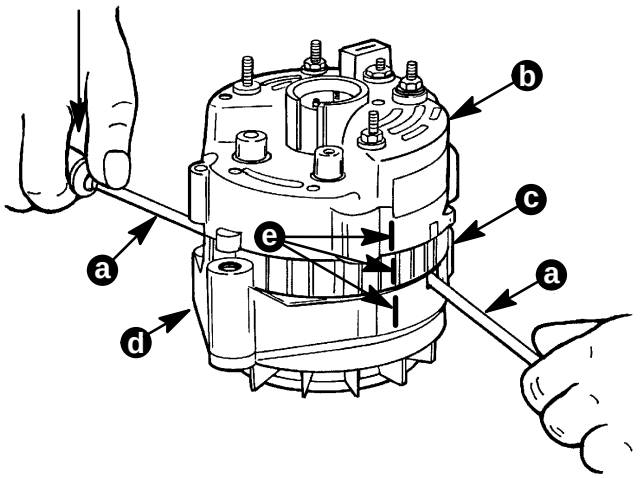
72823

a - Screws
b - Brush/Regulator Assembly
c - Stud Cover Insulator
d - Tie Strap

5. Scribe a mark on rear end frame, stator and front end frame to ensure proper reassembly later.
6. Remove four screws which secure end frames and stator together.

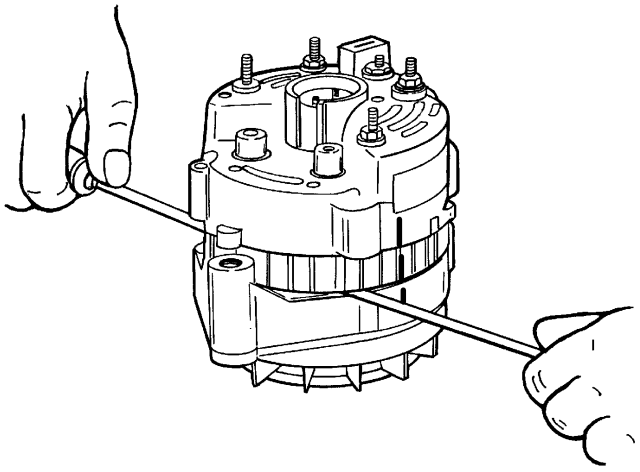
IMPORTANT: DO NOT insert screwdriver blades more than 1/16 in. (1.5 mm) into openings (in next step), as stator windings may be damaged.

7. Separate rear end frame and stator assembly from front end frame and rotor assembly using two thin blade screwdrivers (positioned 180 degrees apart from one another) at the locations shown. Use the two slots shown to initially separate units spacer.



72824

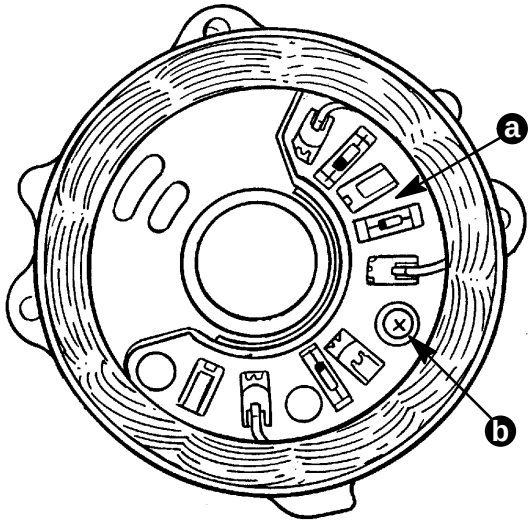
a - DO NOT Insert Screwdriver Blades More than 1/16 In. (1.5 mm) into Slots
b - Rear End Frame
c - Stator
d - Front End Frame
e - Scribe Marks



72825

8. Place rear end frame and stator assembly on the bench with stator downward. Be sure that bench is clean and free of metal chips. Remove nuts, washers, insulators and condenser from output and ground studs.

9. Turn end frame over (stator upward) and remove one Phillips head screw which secures rectifiers to end frame.

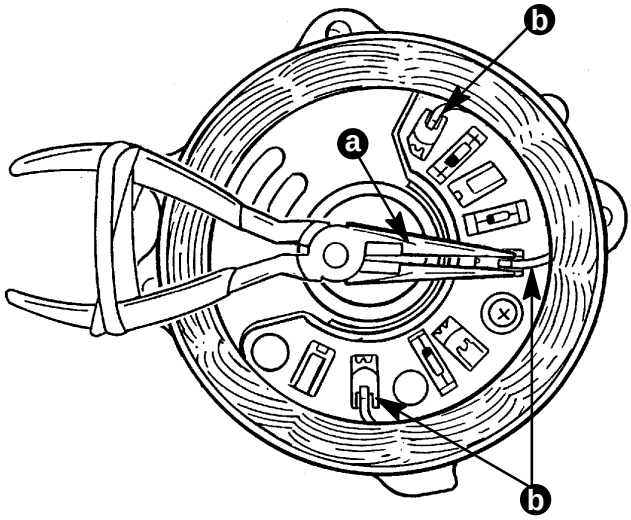


72826

a - Rectifier Assembly
b - Phillips Head Screw

10. Separate stator and rectifier assembly from rear end frame using screwdriver slots.

11. Unsolder the three stator leads from the rectifier heat sink. Place a needle nose pliers on diode terminal between solder joint and diode body to help prevent heat damage to diodes. Unsolder joints as quickly as possible and allow diode terminal to cool before removing pliers.



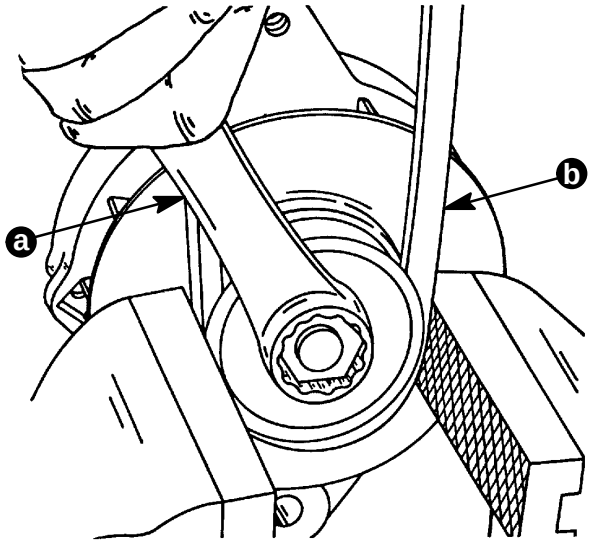
72827

a - Heat Sink
b - Stator Leads (3)

IMPORTANT: With alternator disassembled to this point, stator, rectifier, diodes, and rotor may be tested, as explained under "Component Testing," following.

IMPORTANT: DO NOT clamp vise on rotor pole pieces when removing pulley nut (in next step), as pole pieces may be distorted.

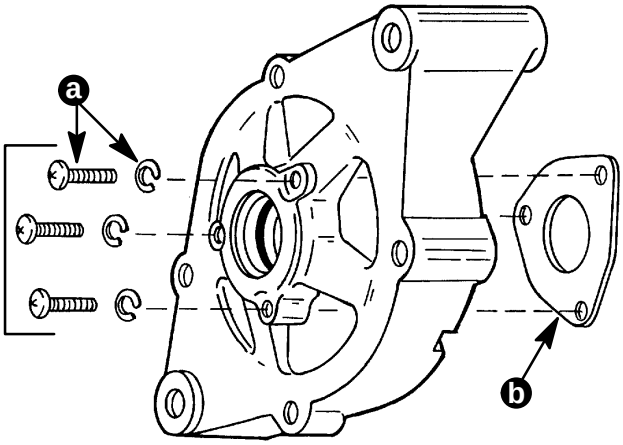
12. Remove pulley retaining nut by clamping pulley in a vise (using an oversize V-belt or protective jaws to protect pulley) and turning nut counterclockwise with a 7/8 in. wrench. Remove lockwasher and slide pulley and fan from shaft. If pulley is difficult to remove, it may be necessary to use a universal puller.



72828

a - 7/8 In. Wrench
b - Over-Sized V-Belt to Protect Pulley

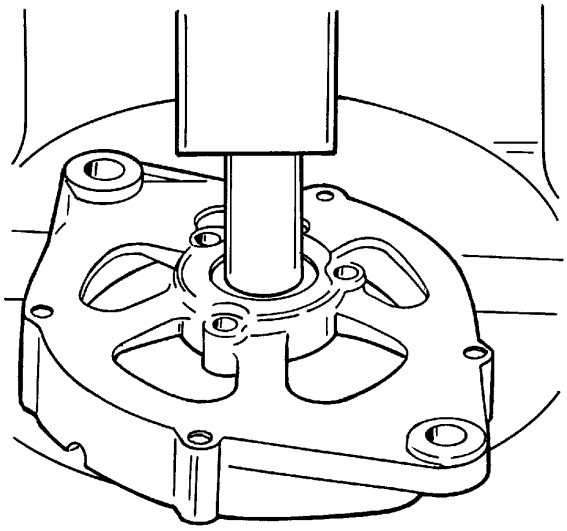
13. Remove the three Phillips head screws and lockwashers which secure the front bearing retaining plate.



72829

a - Phillips Head Screws and Lockwashers
b - Front Bearing Retaining Plate

14. Remove front bearing from front end frame using an arbor press and a suitable size mandrel. (Discard bearing.)



72830

Removing Front Bearing from Front End Frame

15. If rotor slip rings or rear bearing requires replacement, entire rotor must be replaced. Parts cannot be purchased separately.

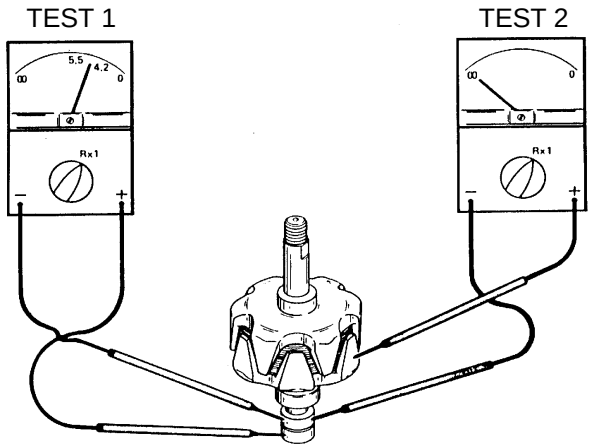
Cleaning and Inspection

1. Clean all parts with a clean, soft cloth. DO NOT use solvent, or electrical components may be damaged.
2. Inspect the following parts for wear and damage:
   a. **Brush/regulator assembly** - inspect for cracked casing, damaged brush leads, poor brush lead solder connections, weak or broken brush springs or worn brushes. Replace brush set if brushes are less than 1/4 in. (6 mm) long.
   b. **Rotor** - inspect for stripped threads, scuffed pole piece fingers or damaged bearing surfaces (because of bearing turning on shaft).
   c. **Rotor-slip rings** - clean slip rings with 400 grain (or finer) polishing cloth while spinning rotor in a lathe. Blow off dust with compressed air. Inspect slip rings for grooves, pits, flat spots or out-of-round [.002 in. (0.051 mm) maximum] and replace rotor, if present.
   d. **Rotor shaft and front end bearings** - inspect for damaged seals, lack of lubrication, discoloration (from overheating) and excessive side or end play. Bearing should turn freely without binding or evidence of rough spots.
   e. **Stator** - inspect for damaged insulation or wires; also inspect insulating enamel for heat discoloration, as this is usually a sign of a shorted or grounded winding or a shorted diode.
   f. **Front and rear end frames** - inspect for cracks, distortion, stripped threads or wear in bearing bore (from bearing outer race spinning in bore). End frame(s) MUST BE replaced, if bearing has spun. Also, inspect bearing retainer recess in front end frame for damage.
   g. **Fan** - inspect for cracked or bent fins, broken welds (bi-rotational fan only) or worn mounting hole (from fan spinning on shaft).
   h. **Pulley** - inspect pulley mounting bore end for wear. Inspect drive surface of pulley sheaves for trueness, excessive wear, grooves, pits, nicks and corrosion. Repair damaged surfaces, if possible, with a fine file and a wire brush or replace pulley, if beyond repair. Drive surfaces MUST BE perfectly true and smooth or drive belt wear will be greatly accelerated.

Component Testing

ROTOR

1. Test rotor field circuit for opens, shorts or high resistance (Test 1), using an ohmmeter (set on R x1 scale), as follows:

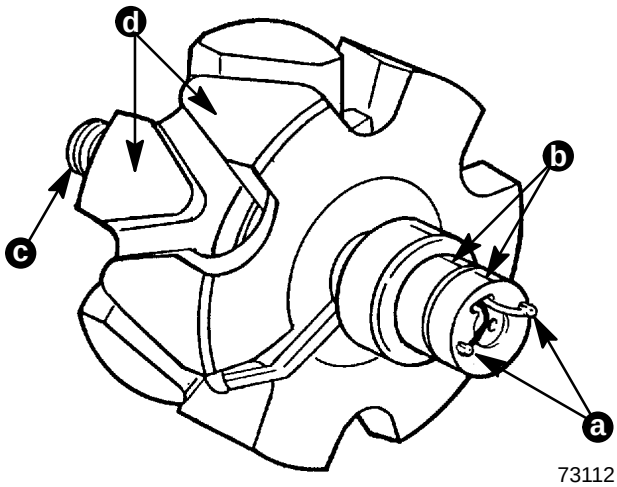


72831

Testing Rotor Field Circuit

   a. Connect one ohmmeter lead to each slip ring.
   b. Ohmmeter reading should be 4.2 to 5.5 ohms with rotor at room temperature 70-80°F (21-26°C).
   c. If reading is high or infinite (no meter movement), high resistance or an open exists in the field circuit. Check for poor connections between field winding leads and slip ring terminals. If cause for open or high resistance cannot be found, connect ohmmeter directly to slip ring terminals. If correct reading is now obtained, or if reading is still high or infinite, replace complete rotor assembly.

d. If reading is low, a short exists in the field circuit. Inspect slip rings to be sure that they are not bent and touching outer slip ring. Also, be sure that excess solder is not shorting terminals to aft slip ring. If cause for short cannot be found, unsolder field winding leads from slip ring terminals and connect ohmmeter directly to leads. If correct reading is now obtained, or if reading is still low, slip rings and rotor field windings are shorted, and complete rotor assembly must be replaced.



73112

a - Field Winding Leads
b - Slip Rings
c - Rotor Shaft
d - Pole Pieces

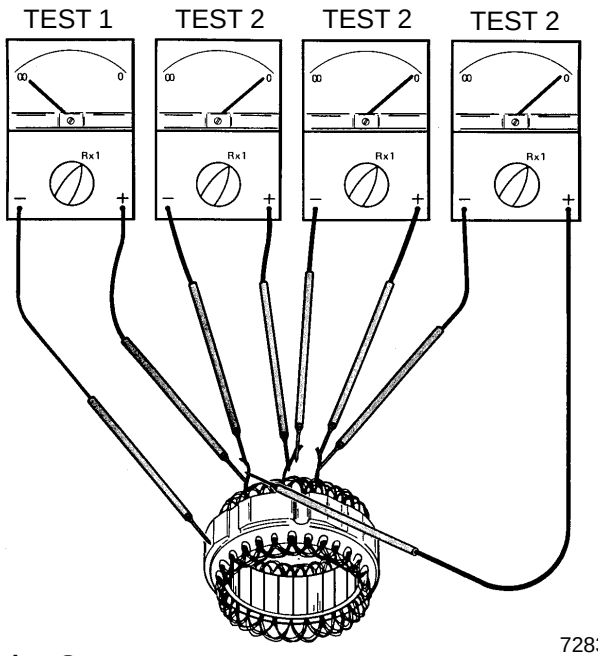
2. Test rotor field circuit for grounds (Test 2), using an ohmmeter (set on R x1 scale) as follows:
   a. Connect one lead of ohmmeter to either slip ring and the other lead to rotor shaft or pole pieces.
   b. Meter should indicate no continuity (meter should not move).
   c. If continuity does exist, complete rotor assembly must be replaced.

IMPORTANT: If alternator has output at low speeds, but no output at high speeds, rotor field winding may be shorting or grounding out, due to centrifugal force. Replace rotor if all other electrical components test good.

STATOR

IMPORTANT: Stator leads MUST BE disconnected from rectifier for this test.

1. Test stator for grounds (Test 1), using an ohmmeter (set on R x1 scale) as follows:
   a. Connect one lead of ohmmeter to one of the stator leads and the other lead to stator frame. Be sure that lead makes good contact with frame.
   b. Meter should indicate no continuity (meter should not move). If continuity does exist, stator is grounded and must be replaced.
2. Test for opens in stator (Test 2), using an ohmmeter (set on R x1 scale) as follows:
   a. Connect ohmmeter between each pair of stator windings (three different ways).
   b. Continuity should be present in all three cases (meter should move). If it does not, one or more of the windings are open and stator must be replaced.



72833

Testing Stator

3. A short in the stator is difficult to detect without special equipment, because of the low windings resistance. If all other electrical components test out good, and alternator fails to produce rated output, stator probably is shorted and should be replaced. Also, examine stator for heat discoloration, as this usually is a sure sign of a short.

RECTIFIER AND DIODE ASSEMBLY

NOTE: *Failure of any component in tests following will require replacement of entire rectifier assembly.*

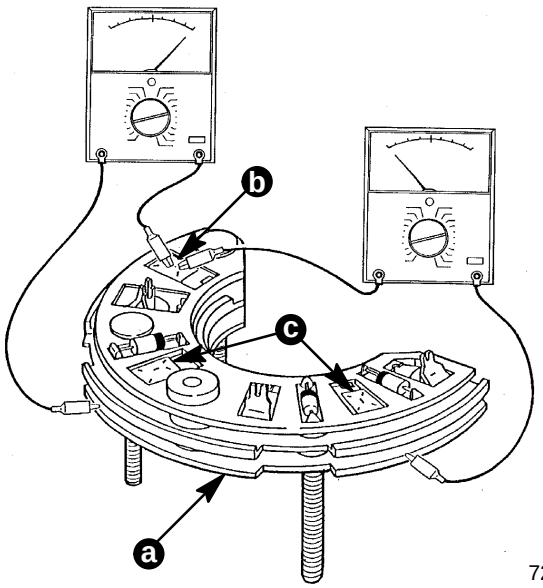
Negative (-) Rectifier

IMPORTANT: Rectifier MUST BE disconnected from stator for this test.

⚠CAUTION

DO NOT use a test instrument with more than a 12 volt source (in the following test), as rectifier may be damaged.

1. Connect one lead of an ohmmeter (set on R x1 scale) to negative (-) rectifier heat sink and the other lead to one of the rectifier terminals. Note the reading.
2. Reverse leads and again note reading.
3. Meter should indicate a high or infinite resistance (no meter movement) when connected one way and a low reading when connected the other. If both readings are high or infinite, rectifier is open. If both readings are low, rectifier is shorted.
4. Repeat Steps 1 through 3 for two other rectifiers in heat sink.
5. Replace assembly if any of the rectifiers is shorted or open.



72147

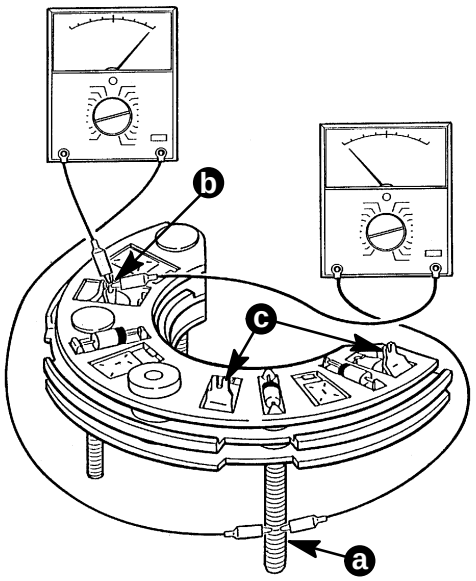
a - Heat Sink
b - Rectifier Terminal
c - Test These Two Rectifiers in Same Manner

Positive (+) Rectifier and Diodes

⚠CAUTION

DO NOT use a test instrument with more than a 12 volt source (in the following test), as rectifier may be damaged.

1. Connect one lead of an ohmmeter (set on R x1 scale) to 1/4 in. stud on positive (+) rectifier heat sink and the other lead to one of the rectifier terminals. Note the meter reading.
2. Reverse leads and again note reading.
3. Meter should indicate a high or infinite resistance (no meter movement) when connected one way and a low reading when connected the other. If both readings are high or infinite, rectifier is open. If both readings are low, rectifier is shorted.
4. Repeat Steps 1 through 3 for two other rectifiers in heat sink.

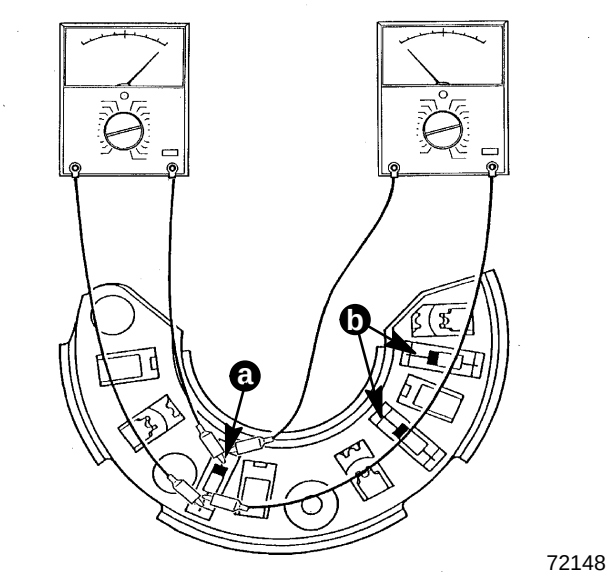


72834

a - Stud
b - Rectifier Terminal
c - Repeat Test between These Terminals and Stud

5. Replace assembly if any one of the rectifiers is shorted or open.

6. Connect one lead of an ohmmeter (set on R x1) to the common side of the diode and the other lead to the other side, of one of the three diodes.



72148

a - Common Side of Diode Circuit Board
b - Repeat Test for These Two Diodes

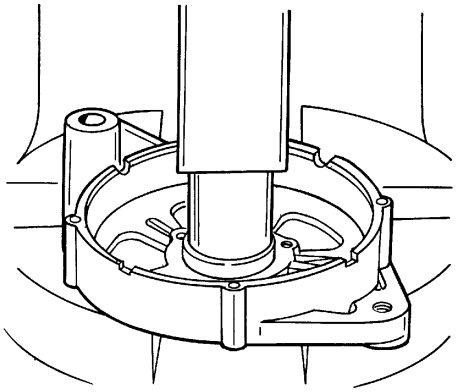
7. Reverse leads and again note reading.
8. Meter should indicate a high or infinite resistance (no meter movement) when connected one way and a low reading when connected the other. If both readings are high or infinite, diode is open. If both readings are low, diode is shorted.
9. Repeat Steps 6 through 8 for the other two diodes.
10. Replace rectifier assembly if any one of the diodes is shorted or open.

CONDENSER

1. Using magneto analyzer and accompanying instructions, perform the following condenser tests:
   a. Condenser Capacity Test (must be .5 mfd).
   b. Condenser Short or Leakage Test.
   c. Condenser Series Resistance Test.
2. Replace condenser if test results are not within specifications.

Reassembly

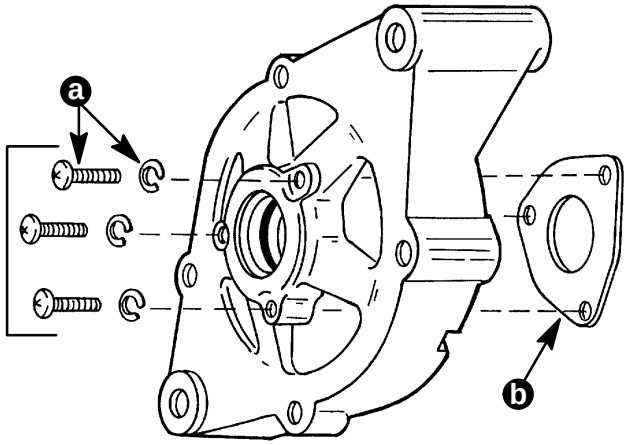
1. Install new front bearing into front end frame bearing bore using an arbor press. If necessary, use a bearing driver that contacts outer race only.



72835

Installing Front Bearing into Front End Frame

2. Install front bearing retaining plate using three Phillips head screws and lockwashers.



72829

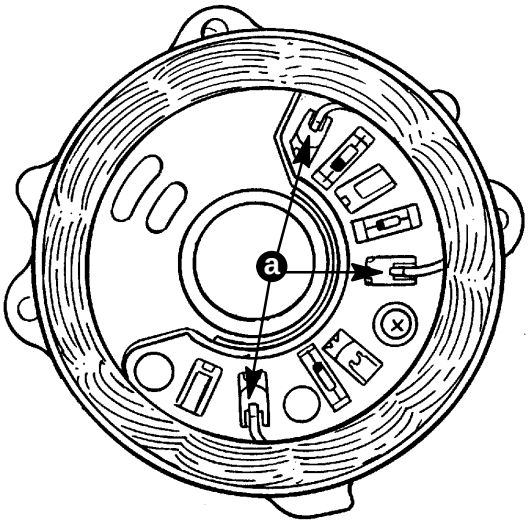
a - Phillips Head Screws and Lockwashers
b - Front Bearing Retaining Plate

3. Slide front end frame over rotor.

IMPORTANT: DO NOT clamp vise on rotor pole pieces when tightening pulley nut (in next step), or pole pieces may be distorted.

4. Slide fan spacer onto rotor shaft. Install fan, pulley, lockwasher and nut on shaft. Clamp pulley in a vise, using protective jaws or an old oversize V-belt to protect pulley, and torque nut to specifications. Tighten vise only enough to allow tightening of nut, as excessive tightening may distort pulley.

5. Assemble stator to rectifier by soldering the three leads to the three rectifier terminals.



72826

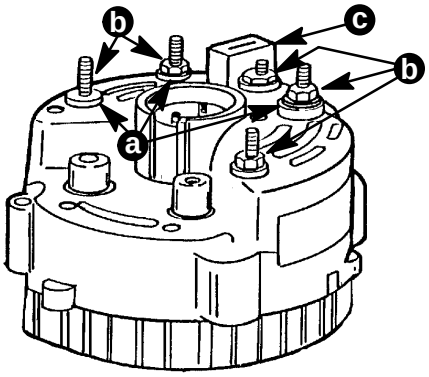
a - Stator Lead Connections

NOTE: *Be sure to connect leads to their original positions.*

6. Install assembled stator and rectifier assembly into rear end frame, aligning scribe marks on each (scribed during disassembly), and install Phillips head screw and washer to retain.

IMPORTANT: The insulating washers MUST BE installed as shown or damage to the alternator will result.

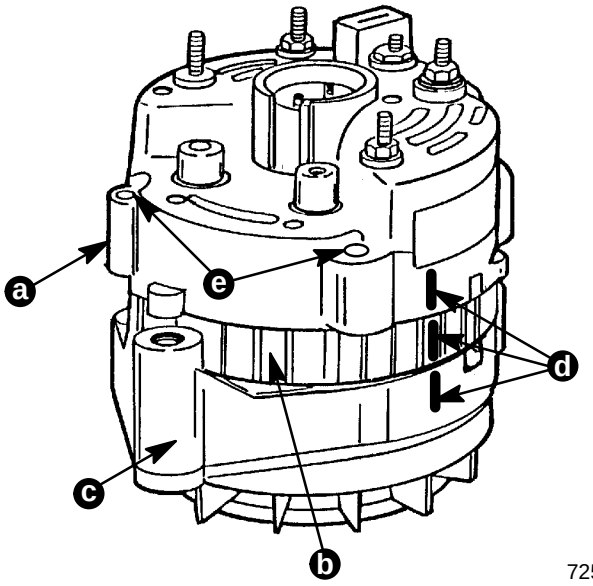
7. Position stator down with rear end frame up and reinstall insulators, nuts and condenser.



72561

a - Insulators (3)
b - Nuts (5) - ONE REMOVED
c - Condenser

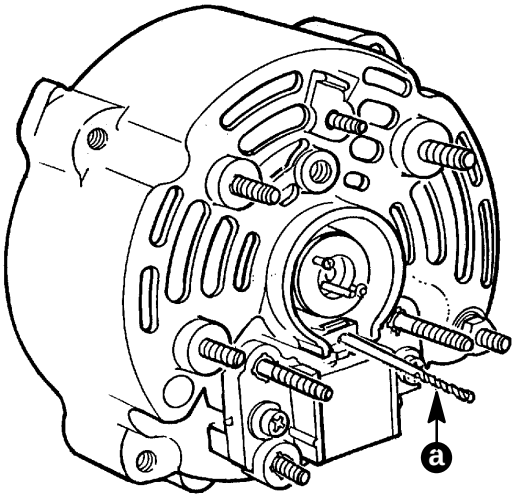
8. Position rear end frame and stator assembly over front end frame and rotor assembly and align scribe marks on each (scribed during disassembly). Hand-press end frames together, then install four screws. Tighten screws securely.



72561

a - Rear End Frame
b - Stator
c - Front End Frame
d - Scribe Marks
e - Insert Screws (4) (Two Hidden)

9. Depress brushes flush with top of brush holder and insert a #54 drill bit or smaller (.050 in.) into hole in brush holder to hold brushes compressed during reassembly.

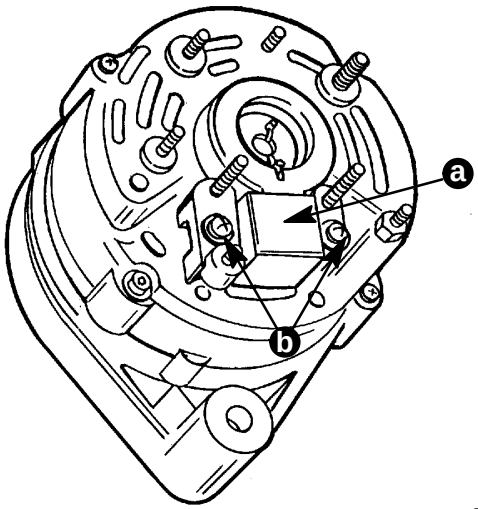


72836

a - Drill Bit

NOTE: *Rubber gasket shown removed for clarity.*

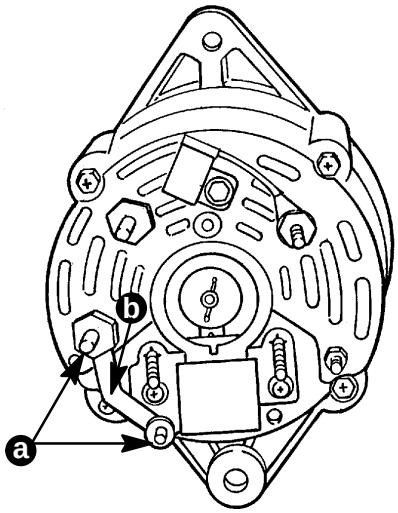
10. Install brush/regulator assembly in rear end frame cavity and secure with two mounting screws, as shown. Tighten screws securely. Remove drill bit to release brushes against slip rings.



72837

a - Brush/Regulator Assembly
b - Mounting Screws

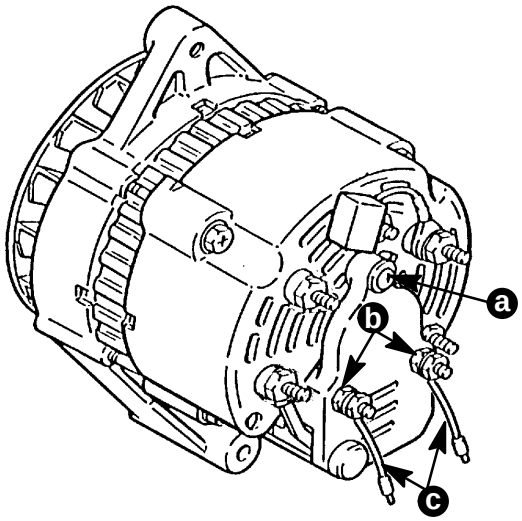
11. Install tie strap to rectifier stud and stud on brush/rectifier assembly. Tighten nuts securely.



72823

a - Studs
b - Tie Strap

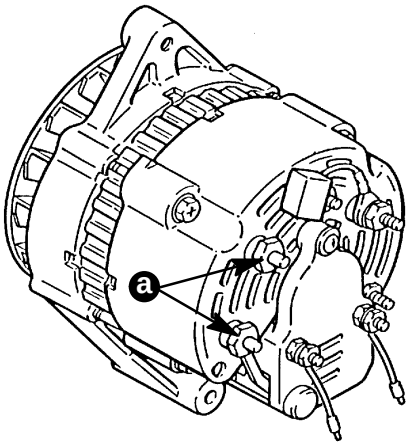
12. Install cover with one Phillips head screw and two nuts. Install two leads with nuts.



72963

a - Phillips Head Screw
b - Nuts (4)
c - Leads

13. Install insulator caps.

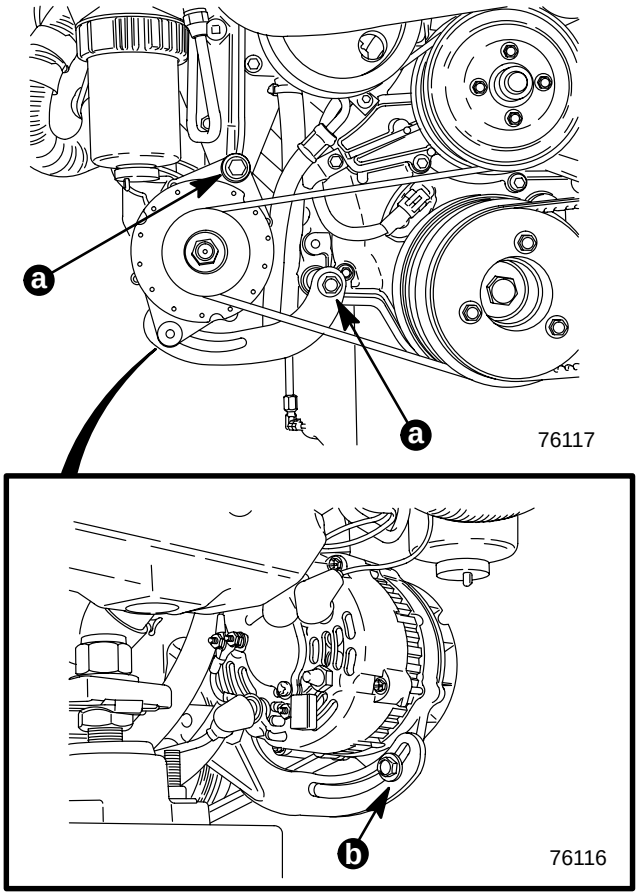


72078

a - Insulator Caps

Installation

1. Install alternator in mounting bracket. DO NOT tighten fastener at this time.
2. Fasten alternator brace to alternator. DO NOT tighten screw at this time.
3. Install support bracket fasteners.

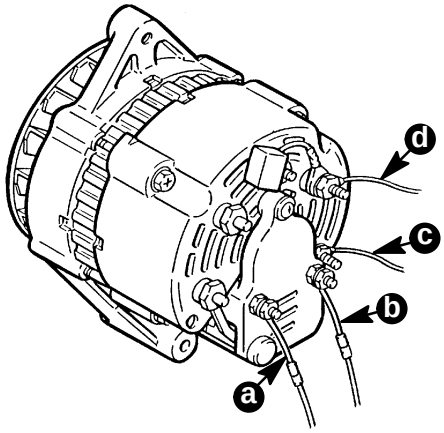


76117

76116

a - Alternator Mounting Hardware
b - Alternator Tensioning Bolt

4. Position alternator drive belt on pulleys and adjust tension as explained under “Drive Belt Tension Adjustment”.
5. Torque fasteners to specifications. Securely tighten all other fasteners.
6. Reconnect wiring harness to alternator. Coat terminals with Quicksilver Liquid Neoprene.
7. Connect negative battery cable to battery.



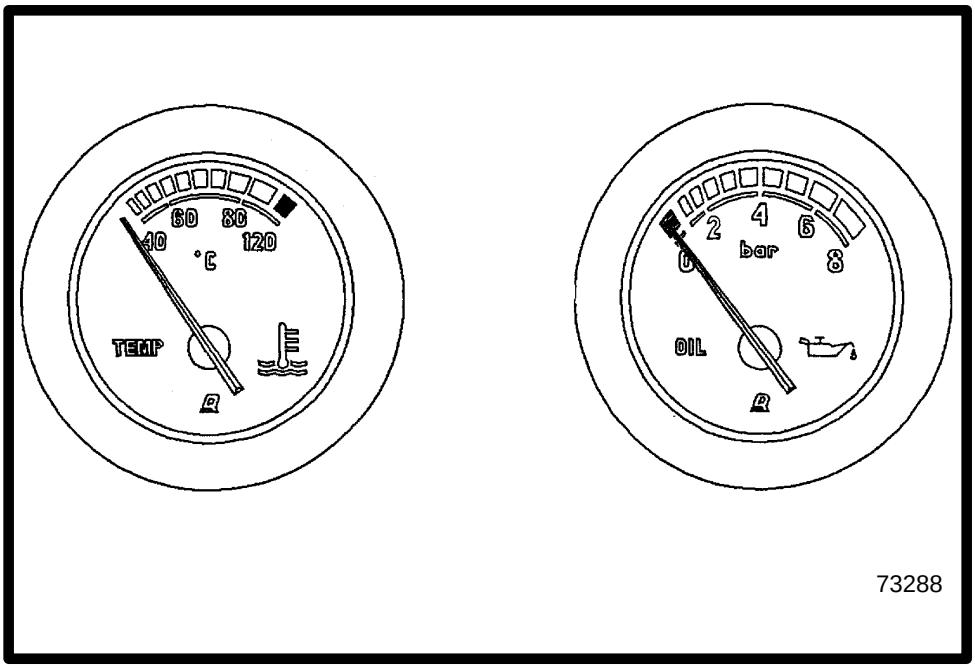
72838

a - Excitation Lead - PURPLE
b - Sensing Lead - RED/PURPLE
c - Ground Lead - BLACK
d - Output Lead - ORANGE

ELECTRICAL SYSTEMS

4

D



INSTRUMENTATION

Index

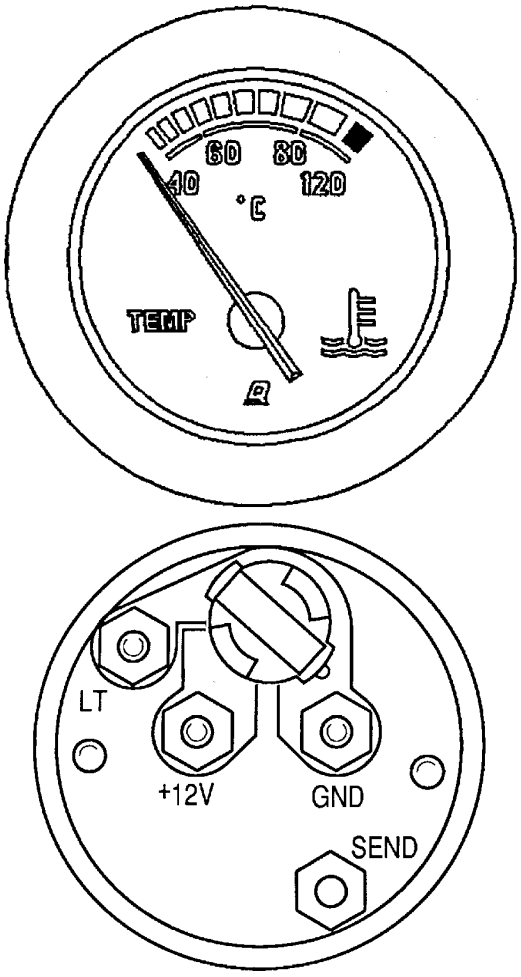
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Wire Color Abbreviations

BLK	Black		PUR or PPL	Purple
BLU	Blue		RED	Red
BRN	Brown		TAN	Tan
GRY	Gray		WHT	White
GRN	Green		YEL	Yellow
ORN	Orange		LIT or LT	Light
PNK	Pink		DRK	Dark

Identification - Gauges



72965

QSI Series Gauge

General

IMPORTANT: If all instruments appear suspect, an electrical overload may have occurred. A fuse may be defective or a circuit breaker may be tripped open. The cause must be found and corrected before replacing fuse or resetting circuit breaker.

If all instruments appear suspect, check the main harness or electrical connector to ensure good contact.

Before testing individual instruments, check the following:

- All wires in circuit are connected.
- Plug in connectors are fully engaged.
- Battery is fully charged.
- All connections are tight and corrosion free.

⚠ CAUTION

Avoid short circuits. It may be necessary to remove instrument panel or Engine System Monitor panel from dashboard to gain access to instruments and switches. Do not allow wires to come in contact with metal or other wires.

Special Information

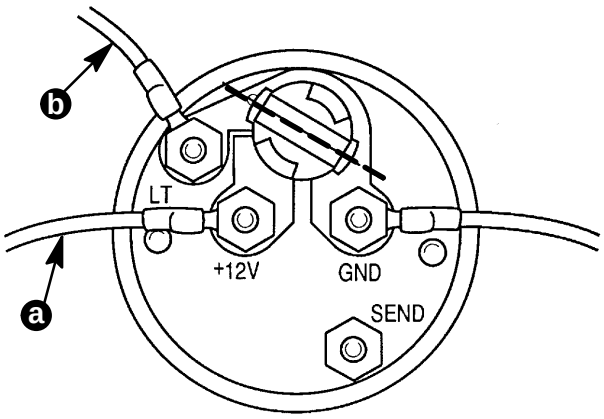
Lighting Options

QSI SERIES

These gauges are equipped with optional illumination lighting. Light bulb socket can be removed and contacts can be aligned to be used with ignition switch lighting circuit +12 V or separate instrumentation lighting circuit LT. Standard is positioned to the separate Panel Lights/Audio Test switch.

IMPORTANT: Light socket must be removed from gauge and turned when adjusting to desired setting. Turning socket while still installed in gauge could result in damage to gauge or socket.

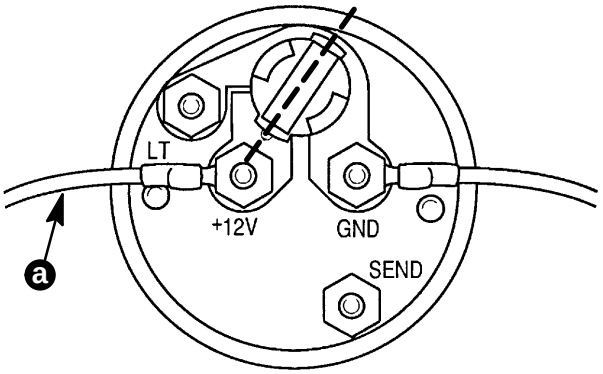
NOTE: *For different lighting effects, colored sleeves are available through the Quicksilver Accessories and can be assembled to the bulb.*



72969

a - +12 V Power Supply from Ignition Switch
b - +12 V Power Supply from Panel Lights/Audio Test Switch (BLUE Wire)

Separate Instrumentation Lighting Circuit Position (Standard Position)



72968

a - +12 V Power Supply from Ignition Switch (PURPLE Wire)

Ignition Switch Lighting Circuit Position (Optional Position)

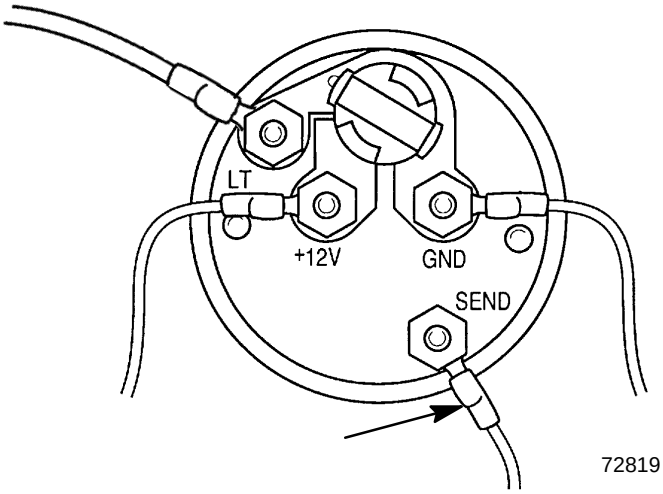
Gauges

Oil Pressure and Water Temperature

IMPORTANT: If testing proves gauge to be defective, it must be replaced as there is no repair available.

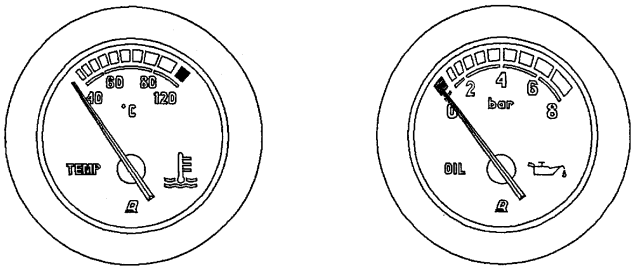
TESTING

1. Turn ignition switch to OFF.
2. Remove wire from terminal S (SEND).



72819

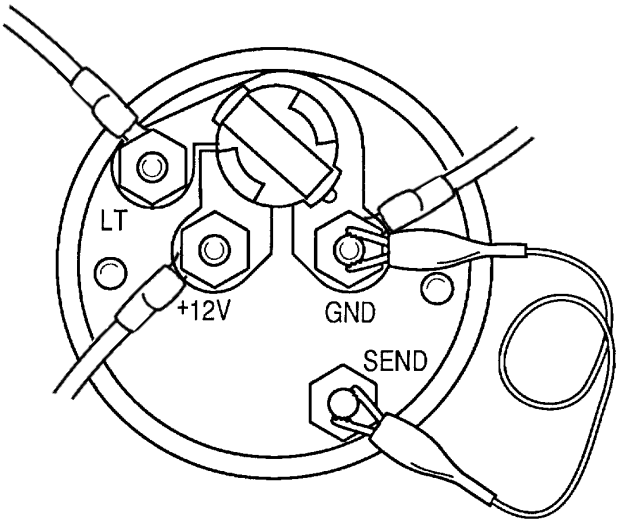
3. Turn ignition switch to RUN. Gauge being tested must be at position A.



Position A

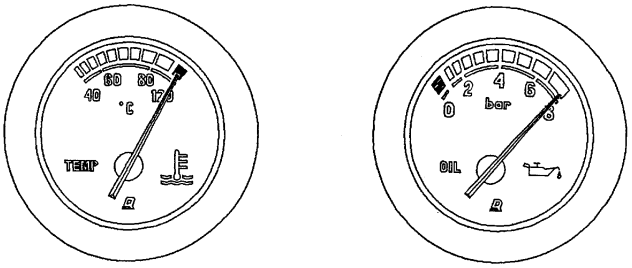
73288

4. Turn ignition switch to OFF.
5. Connect jumper wire from terminal G (GND) to terminal S (SEND).



72748

6. Turn ignition switch to RUN.
7. Indicator needle of gauge being tested must read at position B.



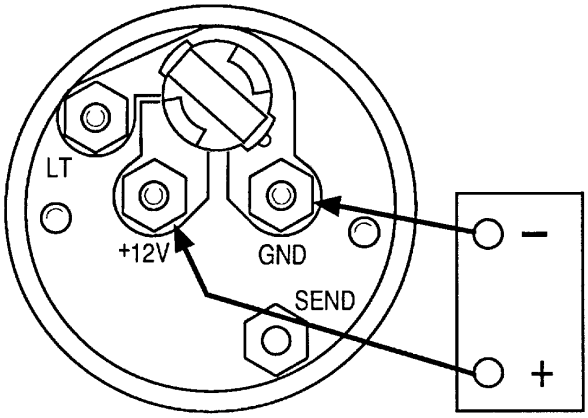
Position B

73289

Volt Meter Gauge

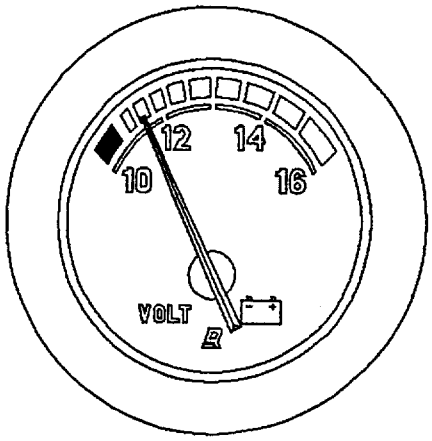
TESTING

1. Remove cables from battery and fully charge battery. Remove wires from back of gauge.
2. Connect negative (-) jumper lead from battery to gauge terminal G (GND).
3. Connect positive (+) jumper lead from battery to gauge terminal I or +12 V.



72750

4. Check gauge reading; if not indicating battery voltage, as shown, replace gauge.

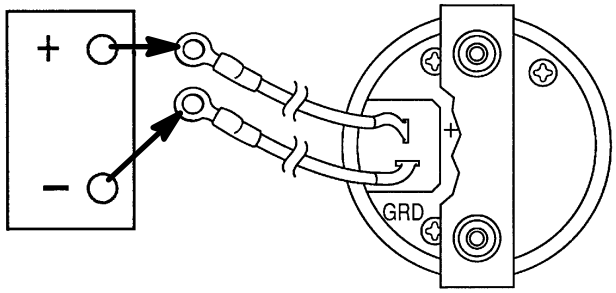


73290

Cruiselog (Engine Hour Meter)

TESTING

1. Remove cables from battery and fully charge battery. Remove wires from back of gauge.
2. Connect negative (-) jumper lead from battery to gauge terminal GND (ground).
3. Connect positive (+) jumper lead from battery to gauge terminal + (12 V).



72750 72815

4. Observe gauge run indicator on face of gauge. If indicator is turning, the gauge is operable. If not replace gauge.

Tachometer

TESTING

1. Connect a service tachometer to engine and compare readings.
2. Replace if not within specifications.

Tachometer Type	Allowable Range
6000 RPM	± 150 RPM
8000 RPM	± 200 RPM

Gauge Replacement

1. Disconnect battery cables from battery.
2. Remove wires from back of gauge.
3. Disconnect light socket wiring if separate.
4. Remove holding strap and remove gauge.
5. Position gauge assembly in appropriate mounting hole.
6. Install holding strap and nuts. Tighten nuts evenly and securely.

IMPORTANT: Do not distort case or bracket by over-tightening.

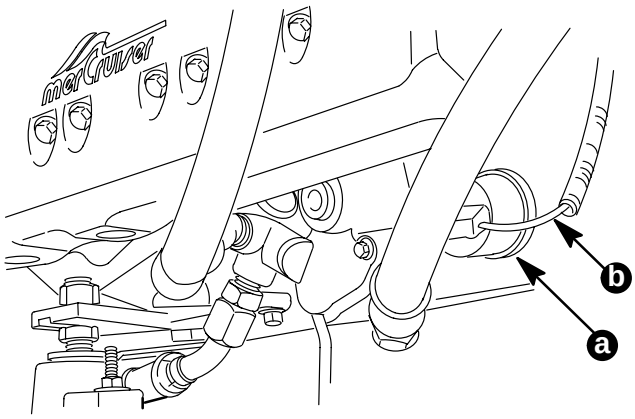
7. Connect ground (BLACK) wire to ground terminal, if gauge is not mounted in metal panel.
8. Connect other wires to gauge as shown in SECTION 4E - “Wiring Diagrams”.
9. Install gauge light socket.
10. Coat all terminals with Quicksilver Liquid Neoprene.
11. Reconnect battery cables to battery.

Senders

Oil Pressure

REMOVAL

1. Remove LIGHT BLUE wire from sender.
2. Using a suitable wrench to hold the fitting, unscrew the sender.



76157

a - Sender
b - LIGHT BLUE Wire

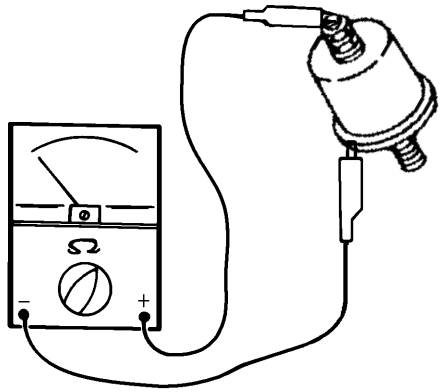
TESTING

IMPORTANT: Use following test procedure for checking accuracy of oil pressure sender only. If oil pressure gauge indicates zero oil pressure, refer to Section 1C - “Troubleshooting”.

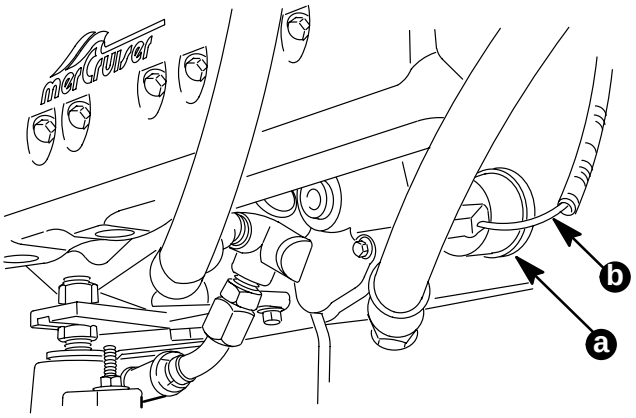
1. Remove LIGHT BLUE wire from sender. Insulate to avoid possible short circuit.
2. Install a manual pressure gauge graduated in at least 10 PSI (100 kPa or 1 bars) increments, using a suitable “T”-fitting arrangement with the existing sender and adaptor or fitting.

3. Connect an ohmmeter between sender terminal and sender case.

NOTE: *Sender shown removed for visual clarity only.*



70686 72936



76157

a - Oil Pressure Sender
b - LIGHT BLUE (LT BLU) Wire

4. Refer to chart. Check the resistance values of the appropriate sender at pressures as shown and verified on manual gauge with engine running. Replace sender if values are not correct.

SINGLE STATION SENDER - 805267	
OIL PRESSURE PSI (kPa)	**OHMS READING**
0 (0)	240 ± 15 Ω
60 (413.7)	103 ± 15 Ω

DUAL STATION SENDER - 805268	
Oil Pressure PSI (kPa)	**Ohms Reading**
0 (0)	120 ± 7 Ω
60 (413.7)	52 ± 7 Ω

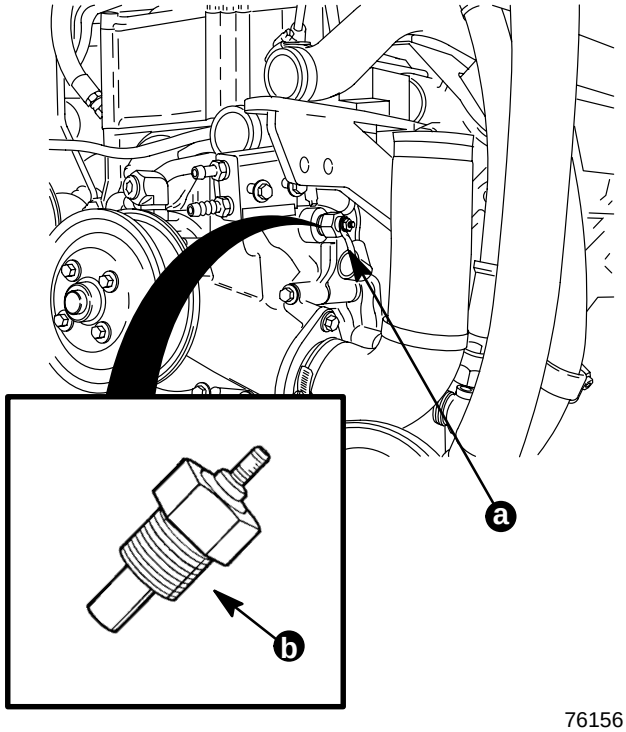
5. When replacing sender, coat threads with Loctite Pipe Sealant with Teflon and install. Tighten securely.

Water Temperature

REMOVAL

IMPORTANT: Use the following test to determine the *accuracy* of the Water Temperature Sender gauge circuit. If gauge indicates NO temperature when running engine refer to the "TROUBLESHOOTING" section.

1. Following instructions in SECTION 6B, drain coolant from closed cooling system.
2. Remove TAN wire from temperature sender, located beneath heat exchanger/closed coolant tank.
3. Remove temperature sender.



76156

a - TAN Wire
b - Water Temperature Sender

TESTING

⚠WARNING

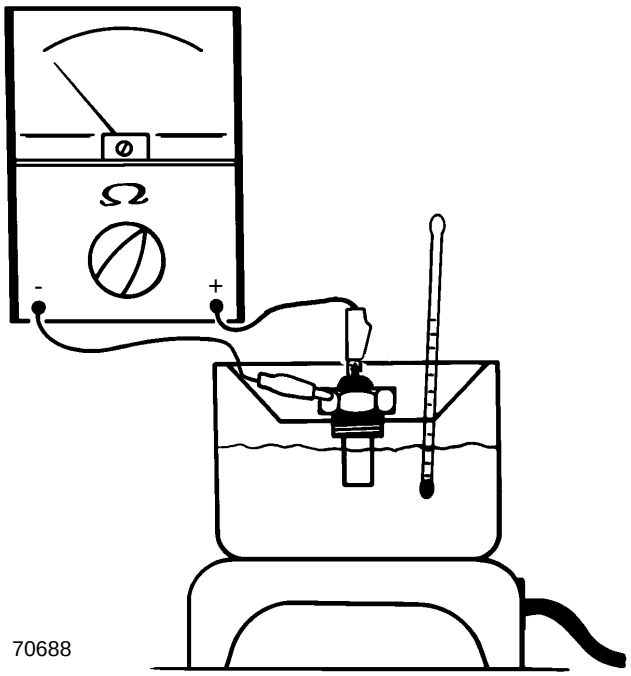
The following test involves the use of intense heat. Failure to follow appropriate procedures or warnings can cause burns which can result in serious personal injury. While performing the following test, observe these general precautions:

- Wear personal protective clothing such as rubber gloves, a non-flammable apron, and eye protection - preferably full face shield or safety glasses.
- The appropriate heat source should only be electric. Heat source should be operated by a qualified person. Be sure to follow all instructions of the manufacturer of the heat source. The heat source should be checked each time it is used to be sure it is functioning properly.
- The thermometer used in the test should be a high temperature thermometer with a maximum reading of at least 300° F (150° C). Under no circumstances should the operator allow temperatures to exceed test specifications.
- Perform test only in a well ventilated area.
- Use a suitable container, such as metal, to hold the sand. Avoid use of glass containers unless the operator first confirms for himself/herself that the glass container is an appropriate high-temperature vessel.
- Because the components will reach high temperatures DO NOT handle materials or components until COMPLETELY cooled.

⚠WARNING

Use only clean, dry sand such as used for general sand blasting purposes. Use of sand containing contaminates could result in hazards such as fire, short circuiting, hot-spots, or other hazards.

1. Follow these instructions:
   a. With an ohmmeter connected as shown following and using a suitable container, thermometer and heat source, suspend sender with tip in sand.
   b. Heat sand and observe temperature on thermometer.
   c. As the temperature rises ohmmeter readings must be within the ranges specified for each temperature. Refer to the chart below for specifications.



70688

SINGLE STATION SENDER - 97257A1	
Test Temperature	**Ohms Reading**
100° F (38° C)	405 - 495 Ω
160° F (71° C)	119 - 140 Ω
220° F (113° C)	44 - 49 Ω

DUAL STATION SENDER - 49734	
Test Temperature	**Ohms Reading**
100° F (38° C)	203 - 247 Ω
160° F (71° C)	59 - 70 Ω
220° F (71° C)	22 - 25 Ω

d. Turn heat source “OFF”. Allow sand and component to cool.

NOTE: *While sand cools you may recheck ohmmeter readings.*

2. Replace sender if ohmmeter readings are other than as shown, for each temperature.

INSTALLATION

1. Apply Loctite Pipe Sealant with Teflon to threads of sender and install. Tighten securely.
2. Following instructions in SECTION 1B - Maintenance, “Filling Closed Cooling Section”.

Switches

Ignition Key Switch

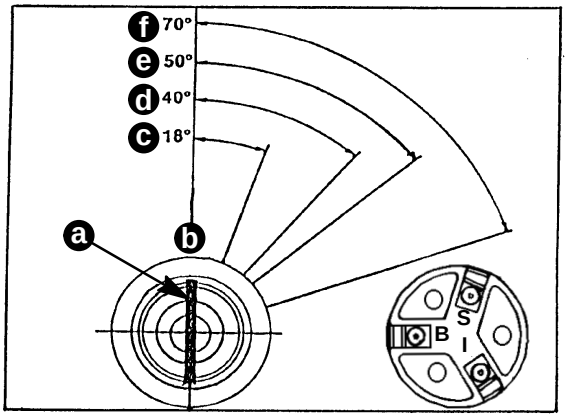
TESTING

1. Before testing key switch, check all fuses and/or circuit breakers in electrical circuit which could prevent operation of starter.

IMPORTANT: Disconnect battery cables from battery before testing ignition key switch with wires still connected to switch.

2. Disconnect battery cables from battery, if proceeding to test switch with wires still connected. With key switch in OFF position, there should be no continuity between switch terminals.
3. With key switch in RUN position, continuity will exist between switch terminals “B” to “I”. There should be no continuity between terminal “S” and any other terminals.
4. With key switch in START, continuity will exist between terminals “B” to “I” and “B” to “S”.

5. Terminals are to make contact at angles shown and to stay in contact condition as switch is rotated toward START.
6. If ignition key switch tests bad, unscrew or unsolder wire connections and remove switch. Test switch again, as in Steps 2-5, preceding. If switch tests good, wiring in harness is bad. There should be no continuity between any switch harness wires with key switch removed.



Key View Back View 74103

a - Key
b - Off
c - Continuity, B to I Terminals
d - Run
e - Continuity, B to S Terminals
f - Start

Audio Warning Test and Panel (dash) Light

The switch provided for the audio warning test and panel (dash) lights is a three-position toggle switch. It must be wired and installed correctly to provide proper operation of the systems.

REMOVAL

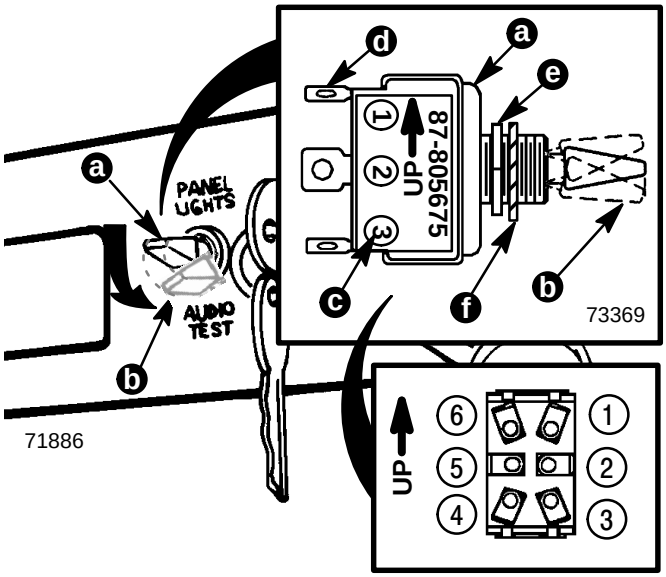
1. Remove hex nut retaining switch to Engine System Monitor Panel.
2. Remove wires from back of switch.

TESTING

1. With switch lever toggled to its spring loaded Audio Test position continuity should exist between terminal numbers 1 and 2 (as indicated by decal). If no continuity exists, replace switch.
2. With switch lever toggled to the panel light “ON” position continuity should exist between terminal numbers 4 and 5 (as indicated by decal). If no continuity exists, replace switch.

INSTALLATION

1. Using screws provided, connect the listed color coded wires to numbered switch terminals as shown:



a - Audio Test/Panel Light Switch
b - Spring-Loaded Audio Test Portion (Direction of Movement DOWN When Installed)
c - Terminal Number(s)
d - Terminal(s)
e - Jamb Nut
f - Locking Washer

Harness Wire (Color Code)	Connect To:	Terminal Number
BLACK (BLK)	▶	2
TAN/BLACK (TAN/BLK)	▶	1
BLUE (BLU)	▶	5
PURPLE (PPL)	▶	4

2. Make sure that all connections are secure. Seal terminals with Liquid Neoprene (92-25711).
3. Install switch in Engine System Monitor panel. Tighten hex nut securely to prevent switch from turning in its mounting hole.

Audio Warning System

The Audio Warning System is divided into two separate circuits. Both circuits have an individual audio warning buzzer that does NOT include any time delay.

One circuit consists of the engine water temperature switch and related wiring. If this switch is activated ("closed") during the operation of the engine, the alarm buzzer will sound and the Engine System Monitor panel light will be illuminated until the problem is corrected or the electrical system is shut off (key switched "OFF").

The other circuit consists of the engine oil pressure switch, the transmission temperature switch [MIE (Inboard) models] or the gear lube monitor bottle switch [MCM (Stern Drive) models) and related wiring. These switches are connected to the audio warning buzzer through a control relay which is activated when the glow plug control system has completed the "preheat cycle". Likewise, the Engine System Monitor panel light is illuminated whenever the respective switch is activated ("closed") until the problem is corrected or the electrical system is shut off (key switched "OFF").

The function of the audio warning buzzer can be tested by holding the toggle lever of the Audio Test switch (on the Engine System Monitor panel) DOWN momentarily, with the key switch in the "RUN" position. If the buzzer sounds the buzzer is operable.

Buzzer

⚠ WARNING

The following test involves the use of electricity. Failure to follow appropriate procedures can cause burns or shock which can result in severe personal injury or death.

TESTING

1. If buzzer does not sound:
   a. Disconnect bullet connectors from suspect buzzer. Connect a 12 volt positive (+) jumper wire to where the PURPLE or PURPLE/YELLOW wire (depending on which buzzer is being tested) was connected. Connect the remaining wire (where the TAN/BLACK or TAN/WHITE was connected) to a clean, unpainted ground or negative (-) connection using a jumper wire.
   b. If buzzer does not sound, replace it.
2. If the buzzer worked in Step 1, reconnect wires and:
   a. Remove wires at the switches involved and briefly jumper the wire ends together. With the key switch in the "RUN" position, the buzzer should sound.
   b. If buzzer sounds, the problem is in the switch(es). Refer to individual switches - "Testing", as follows, and test suspect switch. Replace as instructed.
3. If the buzzer did not sound in Step 2: Refer to wiring diagrams and check wires or connectors to the individual switches. Repair as needed.

Oil Pressure Switch

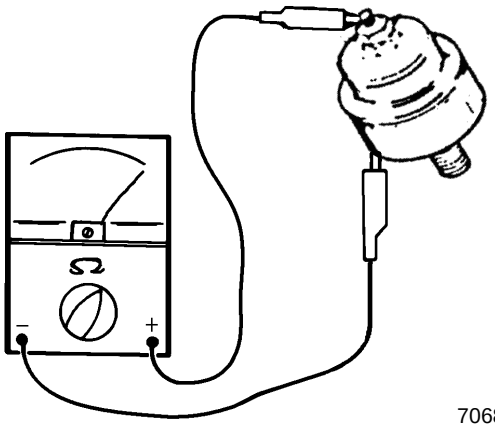
TESTING

When the engine is OFF the switch is normally *closed.*

1. Remove TAN/WHITE wire from sender. Insulate to avoid possible short circuit.
2. Connect continuity meter between sender terminal and sender case [negative (-)]. With engine NOT running, meter should indicate *full* continuity.

NOTE: *Sender shown removed for visual clarity only.*

72817



70686

Typical

OIL PRESSURE PSI (kPa)	SWITCH CONDITION
0 (0)	Closed
4.5 - 7.5 (31 - 52)	Open

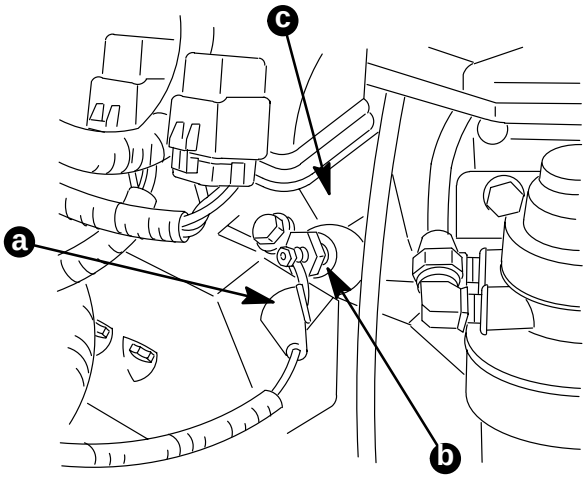
3. When replacing switch, coat threads with Loctite Pipe Sealant with Teflon and install. Tighten securely.

Water Temperature Switch

When engine is COLD audio warning circuit is normally *open.*

REMOVAL

1. Drain coolant from closed cooling system into a suitable container, as outlined in SECTION 6B.
2. Remove TAN wire from temperature switch.



76209

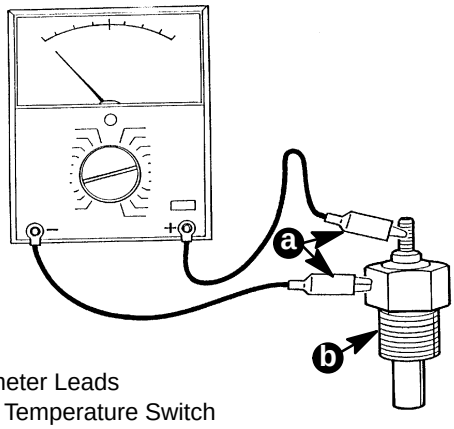
a - TAN Wire
b - Water Temperature Switch
c - Starboard Cylinder Head

3. Remove switch.

TESTING

1. With engine COLD, connect an ohmmeter between water temperature switch terminal (+) and hex (case) for ground (-) as shown.

NOTE: *Shown removed for visual clarity only.*



a - Ohmmeter Leads
b - Water Temperature Switch

72768

2. Switch should read no continuity (*open*). Specifications are shown in the following chart.

TEST TEMPERATURE	SWITCH CONDITION
Less than 220° F (105° C)	Open

3. Replace switch, if continuity exists.

⚠WARNING

The following test involves the use of intense heat. Failure to follow appropriate procedures or warnings can cause burns which can result in severe personal injury. While performing the following test, observe these general precautions:

- **Wear personal protective clothing such as rubber gloves, a non-flammable apron, and eye protection - preferably full face shield or safety glasses.**
- **The appropriate heat source should only be electric. Heat source should be operated by a qualified person. Be sure to follow all instructions of the manufacturer of the heat source. The heat source should be checked each time it is used to be sure it is functioning properly.**
- **The thermometer used in the test should be a high- temperature thermometer with a maximum reading of at least 300°F (150°C). Under no circumstances should the operator allow temperatures to exceed test specifications.**
- **Perform test only in a well ventilated area.**
- **Use a suitable container, such as metal, to hold the sand. Avoid use of glass containers unless the operator first confirms for himself/herself that the glass container is an appropriate high-temperature vessel.**
- **Because the components will reach high temperatures DO NOT handle materials or components until COMPLETELY cooled.**

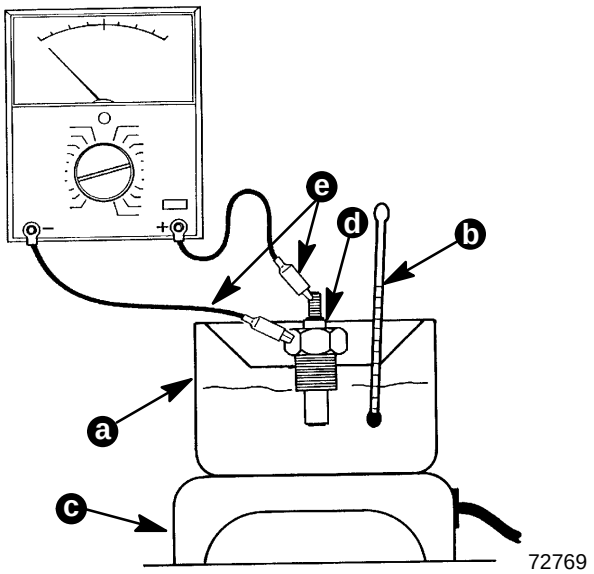
⚠WARNING

Use only clean, dry sand such as used for general sandblasting purposes. Use of sand containing contaminants could result in hazards such as fire, short circuiting, hot-spots, or other hazards.

4. Follow these instructions:

   a. With an ohmmeter connected as outlined and using suitable container, thermometer and heat source, suspend sender with tip in sand.

   b. Heat sand and observe temperature on thermometer.



a - Suitable Container
b - Thermometer
c - Heat Source
d - Water Temperature Sender
e - Ohmmeter Leads

   c. As temperature rises, switch will close and ohmmeter will indicate continuity.

5. Replace switch if it does not *close* (sound buzzer) as shown in the following chart.

TEST TEMPERATURE	SWITCH CONDITION
225 ± 5° F (108 ± 3° C)	Closed

6. Turn heat source off. Allow sand to cool. Note thermometer reading to ensure switch “opens” up at specified temperature as shown previously.

INSTALLATION

1. Apply Loctite Pipe Sealant with Teflon to threads of water temperature switch.
2. Install switch in cylinder head and tighten securely.
3. Connect TAN wire and coat connection with Quicksilver Liquid Neoprene.
4. Refill closed cooling system with approved coolant as outlined in SECTION 6B.

Primary Station Instrumentation

Parts Lists

850766A1 - QSI KIT

PART NUMBER	DESCRIPTION	QTY.
861014	Panel -Primary Station	1
87-805678	Key Switch	1
806546	Rain Cap	1
87-805675A1	Audio Warning/Panel Lights Switch	1
79-805289A1	Tachometer - 5K QSI	1
79-805287A1	Oil Pressure Gauge - 8 bar QSI	1
79-805288A1	Temperature Gauge - 120C QSI	1
79-817032A1	Battery Gauge - QSI	1
79-818163A1	Cruiselog Gauge - QSI	1
90-806330	Template	1

850766A2 - FLAGSHIP KIT

PART NUMBER	DESCRIPTION	QTY.
861014	Primary Station Panel	1
87-805678	Key Switch	1
806546	Rain Cap	1
87-805675A1	Audio Warning/Panel Lights Switch	1
79-850755A1	Tachometer - 5K Flagship	1
79-850759A1	Oil Pressure Gauge - 8 bar Flagship	1
79-850761A1	Temperature Gauge - 120C Flagship	1
79-825291A1	Battery Gauge - Flagship	1
79-825737A1	Cruiselog Gauge - Flagship	1
90-806330	Template	1

850766A3 - ADMIRAL KIT

PART NUMBER	DESCRIPTION	QTY.
861014	Primary Station Panel	1
87-805678	Key Switch	1
806546	Rain Cap	1
87-805675A1	Audio Warning/Panel Lights Switch	1
87-805676A1	Stop Switch	1
79-850756A1	Tachometer - 5K Admiral	1
79-850760A1	Oil Pressure Gauge - 8 bar Admiral	1
79-850762A1	Temperature Gauge - 120C Admiral	1
79-832731A1	Battery Gauge - Admiral	1
79-833115A1	Cruiselog Gauge - Admiral	1
90-806330	Template	1

Tools/Lubricants/Adhesives

DESCRIPTION	PART NUMBER
Liquid Neoprene	92-25711--2
Electrical Tape	Obtain Locally

Preparation for Installation

⚠ WARNING

Always disconnect battery cables before working around electrical system components to prevent injury and/or damage to electrical system.

⚠ CAUTION

Before drilling or cutting any holes, check area behind dashboard for obstructions (braces, cables, etc.).

IMPORTANT: Be certain to take into account the space required to mount the Engine System Monitor panel when determining the location for the instrumentation.

NOTE: *Observe the following, if appropriate:*

- *If dashboard is fiberglass, apply masking tape to area that is to be drilled or cut to help prevent dashboard from cracking.*
- *If dashboard is vinyl covered, remove vinyl, with a razor blade, from area to be drilled or cut, to keep vinyl from tearing.*

TACHOMETER

1. Determine desired location. Before drilling or cutting, make sure that wires will reach gauge. Check area behind dashboard for obstructions such as braces, cables, etc. Be sure to leave clearance between gauges for bezels.
2. Cut or drill a 3-7/16 in. (88 mm) size hole for the the tachometer in dashboard (template on last page).

NOTE: *If installing other gauges it would be appropriate to cut or drill holes for them also at this time. Refer to manufacturers instructions.*

ENGINE SYSTEM MONITOR PANEL

1. Determine desired location. Before drilling or cutting, make sure that wires will reach panel. Check area behind dashboard for obstructions such as braces, cables, etc. Be sure to leave clearance for bezels of gauges.
2. Cut hole in dashboard for Engine System Monitor panel using template 90-806330.
3. Drill four appropriate size holes (depending on material and thickness of dashboard) for panel retaining screws using centerlines on template.

INSTRUMENTATION AND HARNESS WIRES

NOTE: *Refer to Wiring Diagrams in the following.*

1. See wire identification tags (white tags on individual or gathered wires) and route appropriate wires from instrumentation harness through gauge openings in dashboard.
2. Route appropriate wires from instrument harness to Engine System Monitor panel through the opening cut for the panel.

Installation

TACHOMETER

NOTE: *The gauge can be installed with round black bezel already assembled on gauge, or without bezel. The bezel is made to snap on or off.*

1. Set position of switch on back of tachometer to "4=155 PUL/REV."
2. Refer to appropriate wiring diagram and white tag titled "TACHOMETER" on wires. With wires extended through dashboard opening, install tachometer as follows.

⚠CAUTION

Avoid electrical short circuits. Position wires on the back of tachometer (and all gauges) so that they will not rub or contact mounting bracket when it is installed.

a. Remove hex nuts supplied with kit. Secure wires to gauge terminals as shown using the nuts:

Harness Wire (Color Code)	CKT Number	Connect To:	Connection Location On Tachometer
BLACK (BLK)	GND6	▶	"GND" terminal
PURPLE (PPL)	12G	▶	"+12V" terminal
YELLOW (YEL)	101	▶	"SIG" terminal
BLUE (BLU)	LT3	▶	"LT" terminal

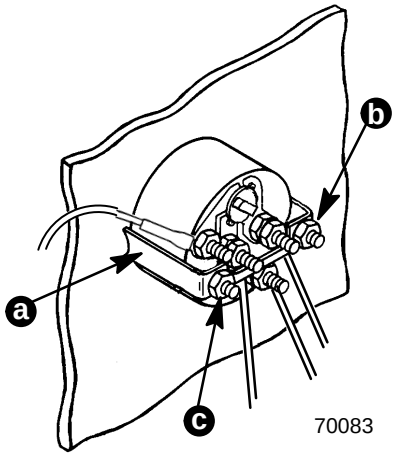
b. Make sure that all connections are secure. Seal terminals with Liquid Neoprene (92-25711).

c. Place tachometer into dashboard.

d. Install mounting bracket as shown.

e. Attach the two hex nuts to studs for bracket.

f. Tighten nuts until gauge is secure. DO NOT over-tighten.



Typical

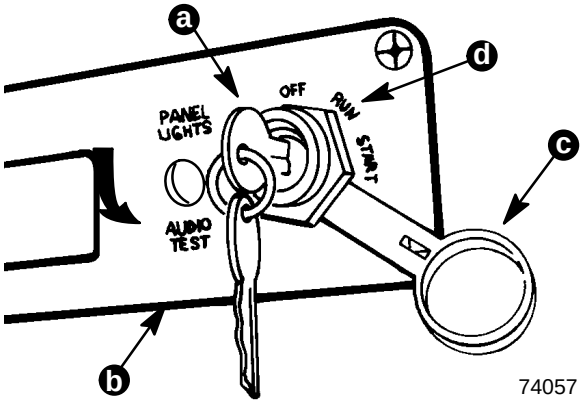
a - Mounting Bracket
b - Mounting Studs and Hex Nuts

Engine System Monitor Panel

INSTALLING AND WIRING SWITCHES

Key Switch

1. Install jamb nut, and then locking washer, on switch threaded portion. Position switch in panel. Install rain cap on switch threaded portion. Secure to panel using hex nut. Tighten securely, to prevent switch from turning in hole. DO NOT overtighten.



a - Key Switch
b - Engine System Monitor Panel
c - Rain Cap
d - Hex Nut

2. Follow instructions “a” and “b”. Refer to appropriate Wiring Diagram.

   a. Using screws provided, connect the listed color coded wires to lettered switch terminals as shown:

Harness Wire (Color Code)	CKT Number	Connect To:	Terminal Letter
RED (RED)	15C	▶	“B”
PURPLE (PPL)	34DA	▶	“I”
PURPLE (PUR)	12C	▶	“S”

   b. Make sure that all connections are secure. Seal terminals with Liquid Neoprene (92-25711).

3. Connect neutral safety switch wiring to remote control (MCM Models). Refer to appropriate Wiring Diagram.

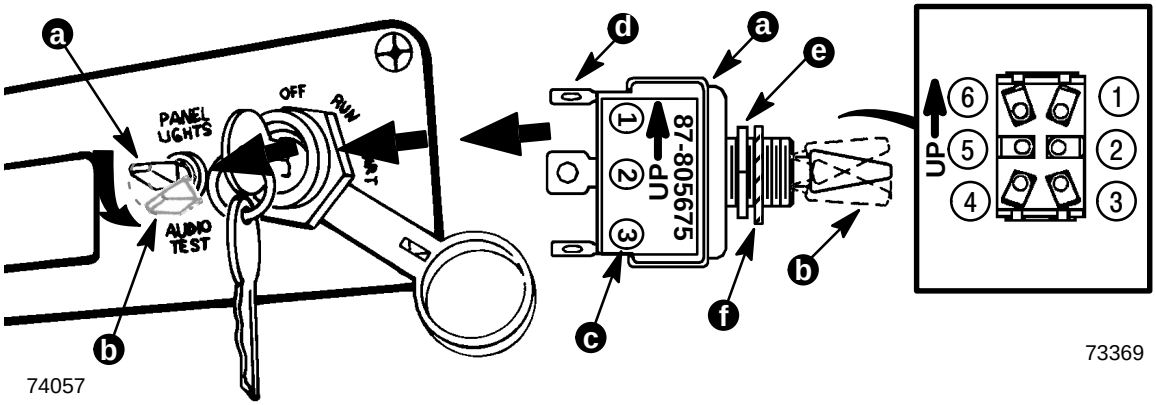
Audio Warning Test and Panel (Dash) Light

The switch provided for the audio warning test and panel (dash) lights is a three-position toggle switch. It must be wired and installed correctly to provide proper operation of the systems.

1. Hold the switch in your hand and press the switch toggle lever into its spring loaded momentary position. You must install the switch so that the “spring loaded”, Audio Test end of the switch is oriented **DOWN** once the panel is installed in the boat.

IMPORTANT: The decal on the side of the switch with the arrow and the word “UP” refer to the position of the switch *when installed on the panel*. The circled numbers refer to wire terminals.

2. Install jamb nut, and then locking washer, on switch threaded portion. Secure to panel using knurled nut. Tighten securely, to prevent switch from turning in hole. DO NOT overtighten.



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a - Audio Test/Panel Light Switch
b - Spring-Loaded Audio Test Portion (Direction of Movement DOWN When Installed)
c - Terminal Number(s)
d - Terminal(s)
e - Jamb Nut
f - Locking Washer

3. Follow instructions “a” and “b”. Refer to appropriate Wiring Diagram.
   a. Using screws provided, connect the listed color coded wires to numbered switch terminals as shown:

Harness Wire (Color Code)	CKT Number	Connect To:	Terminal Number
BLACK (BLK)	16C	▶	2
YELLOW (YEL)	40A	▶	1
BLUE (BLU)	LT1	▶	5
PURPLE (PPL)	12C	▶	4

   b. Make sure that all connections are secure. Seal terminals with Liquid Neoprene (92-25711).

WIRING THE INDICATOR LIGHTS

1. Follow instructions “a” – “d”. Refer to appropriate MCM or MIE Second Station Instrumentation Wiring Diagram.
   a. Locate wire identification white tag titled “INDICATOR LAMPS”.

IMPORTANT: Be certain each bullet connection is properly seated and seal is not deformed after connecting.

2. Connect to individual lights as shown:

Harness Wire (Color Code)	CKT Number	Connect To:	Connection Location
YELLOW (YEL)	40D	▶	Black Wire tagged “CHK”
TAN (TAN)	118B	▶	Black Wire tagged “TEMP”
LIGHT BLUE (LTBLU)	117B	▶	Black Wire tagged “OIL”
GREEN (GRN)	109	▶	Black Wire tagged “BATT”
WHITE (WHT)	40BC	▶	Black Wire tagged “GLOW”

MOUNTING THE PANEL

1. Apply silicone sealing compound to contact surfaces on dashboard.
2. Install panel with the four screws provided, or those selected previously based on material and thickness of dashboard.

Instrumentation and Harness Wires

1. Mount gauges according to instructions provided with individual gauges.
2. Connect extension harness to instrument harness end. Connector collar must be fully engaged and secure. Tighten *threaded* connector collar.
3. Route extension harnesses back to engine. Fasten harnesses to the boat at least every 18 in. (460 mm), using appropriate fasteners.

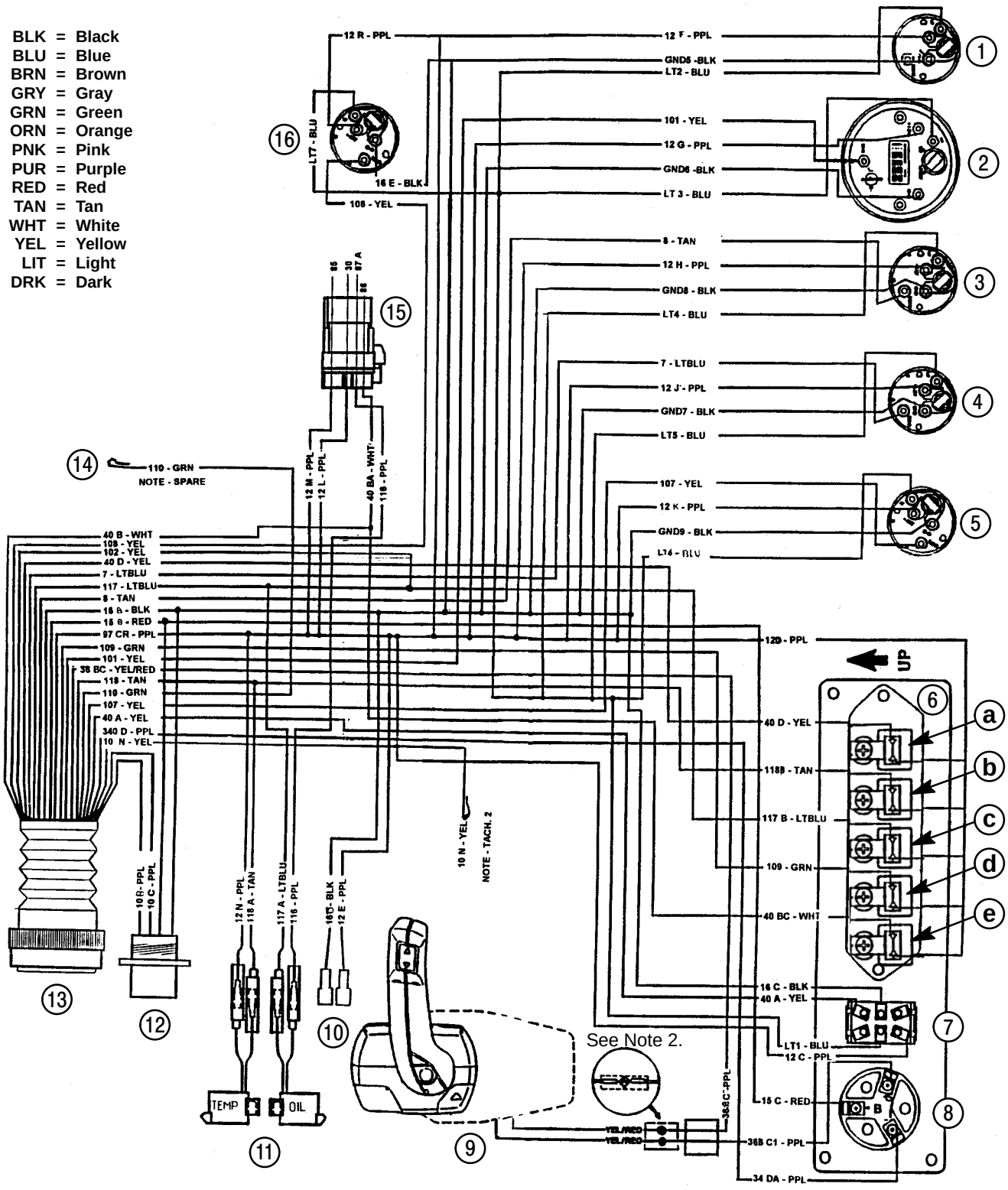
IMPORTANT: When routing any wiring extension harness back to the engine, make sure that the harness does not rub or get pinched.

4. Connect extension harness to engine harness end. Connector collars must be fully engaged. Tighten *threaded* connector collar of extension harness onto connector on side of electrical box.

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Wiring Diagram

BLK = Black
BLU = Blue
BRN = Brown
GRY = Gray
GRN = Green
ORN = Orange
PNK = Pink
PUR = Purple
RED = Red
TAN = Tan
WHT = White
YEL = Yellow
LIT = Light
DRK = Dark



75927

1 - Voltmeter
2 - Tachometer
3 - Coolant Temperature
4 - Oil Pressure
5 - Trim Gauge
6 - Engine System Monitor

a - Check Engine Light
b - Engine Coolant High Temperature/
Low Gear Lube Monitor Light
c - Low Oil Pressure Warning Light
d - Charge Indicator Light
e - Preheat Indicator Light

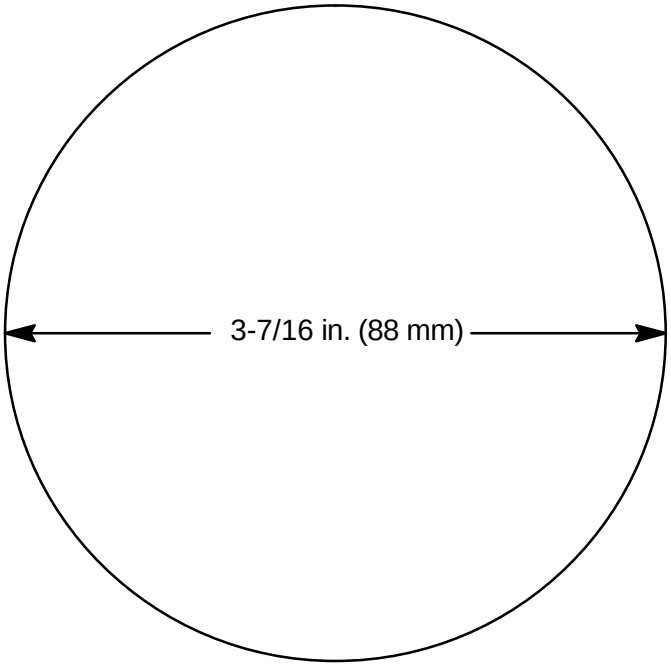
7 - Panel Lights/Audio Warning Test Switch
8 - Key Switch
9 - Neutral Start Safety Circuit/Remote Control
10- Hour Meter Connection (Optional)
11- Audio Warning Horns
12- Diagnostic Tool Connection
13- Harness Connector
14- Wire Not Used (See Note 1)
15- Wait-to-Start Relay
16- Fuel gauge (Optional)

Note 1: Tape wire with at least two layers of electrical tape.

Note 2: Connect wires together with screw and hex nut. Apply Liquid Neoprene to connection and slide rubber sleeve over connection.

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Template



Drilling Hole Template for Quicksilver Tachometer

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Second Station Stop/Start

Parts List

850769A1 - QSI KIT

PART NUMBER	DESCRIPTION	QTY.
861428	Engine System Monitor Panel (Second Station)	1
87-805675A1	Audio Test / Panel Light Switch	1
87-805676A1	Start Switch	1
87-805677A1	Stop Switch	1
853454	Relay Assembly	1
79-805289A1	Tachometer Kit , QSI (5K)	1
90-806330	Engine System Monitor Panel Template	1

850769A2 - FLAGSHIP KIT

PART NUMBER	DESCRIPTION	QTY.
861428	Engine System Monitor Panel (Second Station)	1
87-805675A1	Audio Test / Panel Light Switch	1
87-805676A1	Start Switch	1
87-805677A1	Stop Switch	1
853454	Relay Assembly	1
79-850755A1	Tachometer Kit , Flagship (5K)	1
90-806330	Engine System Monitor Panel Template	1

850769A3 - ADMIRAL KIT

PART NUMBER	DESCRIPTION	QTY.
861428	Engine System Monitor Panel (Second Station)	1
87-805675A1	Audio Test / Panel Light Switch	1
87-805676A1	Start Switch	1
87-805677A1	Stop Switch	1
853454	Relay Assembly	1
79-850756A1	Tachometer Kit , Admiral (5K)	1
90-806330	Engine System Monitor Panel Template	1

Tools/Lubricants/Adhesives

DESCRIPTION	PART NUMBER
Liquid Neoprene	92-25711--2
Electrical Tape	Obtain Locally

Preparation for Installation

⚠WARNING

Always disconnect battery cables before working around electrical system components to prevent injury and/or damage to electrical system.

⚠CAUTION

Before drilling or cutting any holes, check area behind dashboard for obstructions (braces, cables, etc.).

⚠CAUTION

Avoid electrical system or component malfunction. DO NOT install STARTER switch in place of STOP switch (or vice versa) while following instructions for “Installation, - Engine System Monitor Panel, Switches”.

IMPORTANT: Be certain to take into account the space required to mount the Engine System Monitor panel when determining the location for the instrumentation.

NOTE: *Observe the following, if appropriate:*

- *If dashboard is fiberglass, apply masking tape to area that is to be drilled or cut to help prevent dashboard from cracking.*
- *If dashboard is vinyl covered, remove vinyl, with a razor blade, from area to be drilled or cut, to keep vinyl from tearing.*

TACHOMETER

1. Determine desired location. Before drilling or cutting, make sure that wires will reach gauge. Check area behind dashboard for obstructions such as braces, cables, etc. Be sure to leave clearance between gauges for bezels.
2. Cut or drill a 3-7/16 in. (88 mm) size hole for the the tachometer in dashboard (template on last page).

NOTE: *If installing other gauges it would be appropriate to cut or drill holes for them at this time. Refer to manufacturers instructions.*

ENGINE SYSTEM MONITOR PANEL

1. Determine desired location. Before drilling or cutting, make sure that wires will reach panel. Check area behind dashboard for obstructions such as braces, cables, etc. Be sure to leave clearance for bezels of gauges.
2. Cut hole in dashboard for Engine System Monitor panel using template 90-806330.
3. Drill four appropriate size holes (depending on material and thickness of dashboard) for panel retaining screws using centerlines on template.

Instrumentation and Harness - Wires

NOTE: *Refer to Wiring Diagrams in the following.*

1. See wire identification tags (white tags on individual or gathered wires) and route appropriate wires from instrumentation harness through gauge openings in dashboard.
2. Route appropriate wires from instrument harness to Engine System Monitor panel through the opening cut for the panel.

Installation

TACHOMETER

NOTE: *The gauge can be installed with round black bezel already assembled on gauge, or without bezel. The bezel is made to snap on or off.*

1. Set position of switch on back of tachometer to “4=155 PUL/REV.”.
2. Refer to appropriate wiring diagram and white tag titled “TACHOMETER” on wires. With wires extended through dashboard opening, install tachometer as follows.

⚠CAUTION

Avoid electrical short circuits. Position wires on the back of tachometer (and all gauges) so that they will not rub or contact mounting bracket when it is installed.

a. Remove hex nuts supplied with kit. Secure wires to gauge terminals as shown using the nuts:

Harness Wire (Color Code)	CKT Number	Connect To:	Connection Location On Tachometer
BLACK (BLK)	GND6	▶	“GND” terminal
PURPLE (PPL)	12G	▶	“+12V” terminal
YELLOW (YEL)	101	▶	“SIG” terminal
BLUE (BLU)	LT3	▶	“LT” terminal

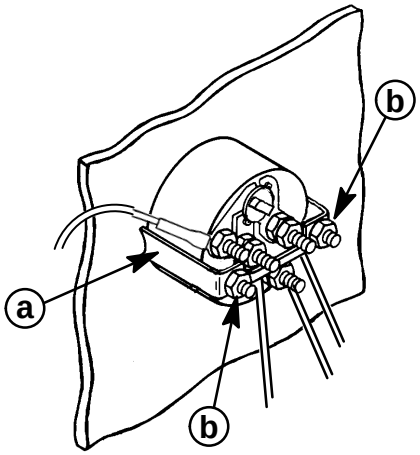
b. Make sure that all connections are secure. Seal terminals with Liquid Neoprene (92-25711).

c. Place tachometer into dashboard.

d. Install mounting bracket as shown.

e. Attach the two hex nuts to studs for bracket.

f. Tighten nuts until gauge is secure. DO NOT over-tighten.



70083

Typical

a - Mounting Bracket
b - Mounting Studs and Hex Nuts

Engine System Monitor Panel

INSTALLING AND WIRING SWITCHES

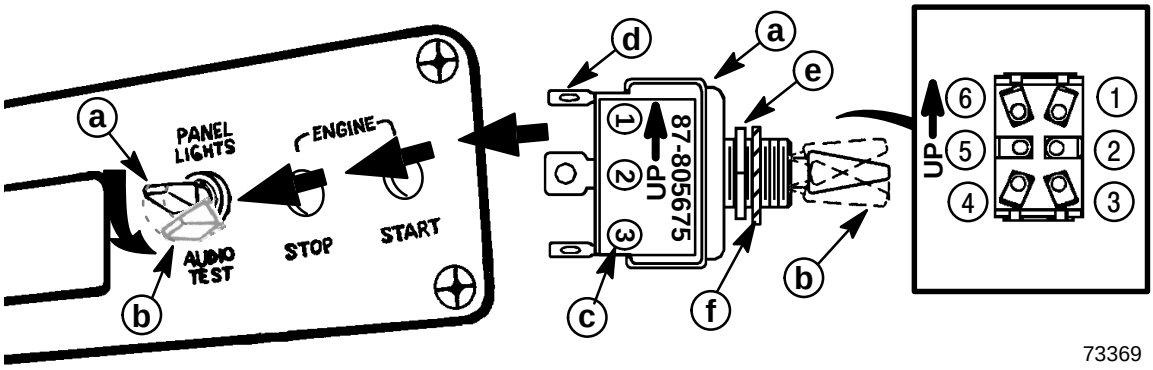
Audio Warning Test and Panel (Dash) Light

The switch provided for the audio warning test and panel (dash) lights is a three-position toggle switch. It must be wired and installed correctly to provide proper operation of the systems.

1. Hold the switch in your hand and press the switch toggle lever into its spring loaded momentary position. You must install the switch so that the “spring loaded”, Audio Test end of the switch is oriented **DOWN** once the panel is installed in the boat.

IMPORTANT: The decal on the side of the switch with the arrow and the word “UP” refer to the position of the switch *when installed on the panel*. The circled numbers refer to wire terminals.

2. Install jamb nut, and then locking washer, on switch threaded portion. Secure to panel using knurled nut. Tighten securely, to prevent switch from turning in hole. DO NOT overtighten.



74057

73369

a - Audio Test/Panel Light Switch
b - Spring-Loaded Audio Test Portion (Direction of Movement DOWN When Installed)
c - Terminal Number(s)
d - Terminal(s)
e - Jamb Nut
f - Locking Washer

3. Follow instructions “a” and “b”. Refer to appropriate Wiring Diagram.

   a. Using screws provided, connect the listed color coded wires to numbered switch terminals as shown:

Harness Wire (Color Code)	CKT Number	Connect To:	Terminal Number
BLACK (BLK)	16C	▶	2
YELLOW (YEL)	40A	▶	1
BLUE (BLU)	LT1	▶	5
PURPLE (PPL)	12C	▶	4

   b. Make sure that all connections are secure. Seal terminals with Liquid Neoprene (92-25711).

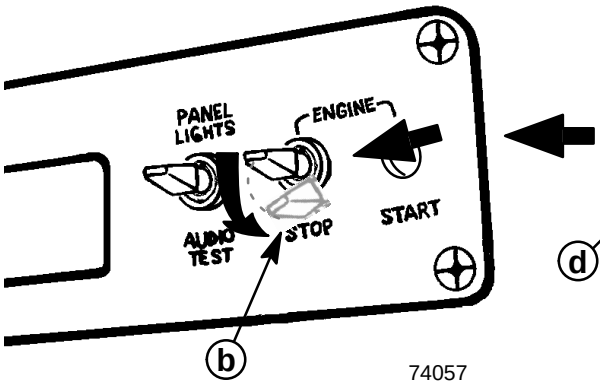
Stop Switch

The “STOP” switch, provided for stopping the engine at this second station, is a single-pole, momentarily *“open”* switch.

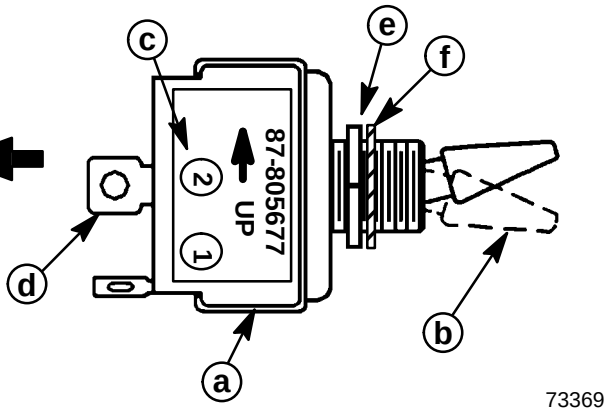
1. Hold the switch in your hand and press the switch toggle lever into its spring loaded momentary position. You must install the switch so that the “spring loaded” end of the switch is oriented **DOWN** once the panel is installed in the boat.

IMPORTANT: The decal on the side of the switch with the arrow and the word “UP” refers to the position of the switch *when installed on the panel*. The circled numbers refer to wire terminals.

2. Install jamb nut, and then locking washer, on switch threaded portion. Secure to panel using knurled nut. Tighten securely, to prevent switch from turning in hole. DO NOT overtighten.



74057



73369

a - Stop Switch
b - Toggle Lever Spring Loaded Position (Direction of Movement DOWN When Installed)
c - Terminal Number(s)
d - Terminal(s)
e - Jamb Nut
f - Locking Washer

3. Follow instructions “a” and “b”. Refer to appropriate Wiring Diagram.

   a. Using screws provided, install wires to appropriate switch and gauge terminals as shown:

Harness 0r Jumper Wire (Color Code)	CKT Number	Connect To:	Terminal Number and/or Connection Location
BLACK (BLK) (jumper wire in kit, taped to relay wires)	16G	▶	1
			“GRD” terminal on a gauge mounted nearest the panel
GREEN (GRN) [tagged “SPARE”] (See Note 1.)	110	▶	2

Note 1.: Wire may be sta-strapped to instrument harness near connector collar.

   b. Make sure that all connections are secure. Seal terminals with Liquid Neoprene (92-25711).

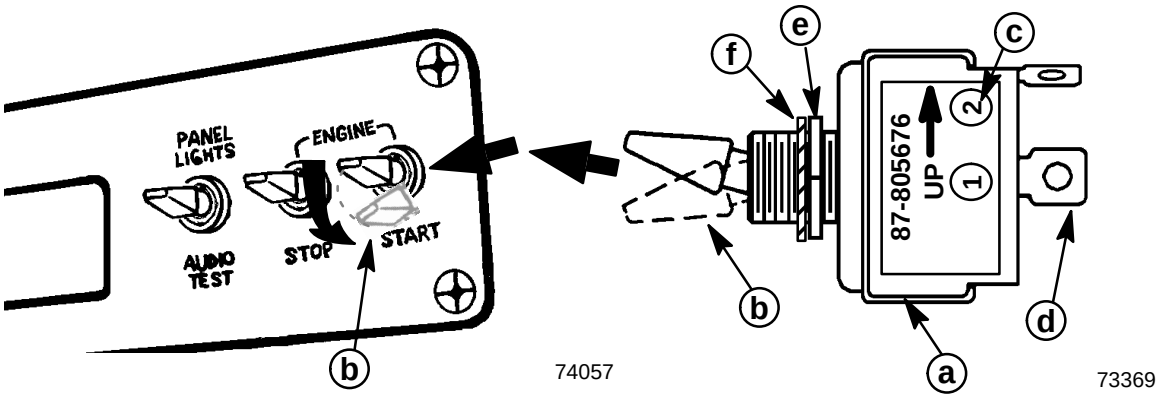
Start Switch

The “START” switch, provided for starting the engine at this second station, is a single-pole, momentarily *“closed”* switch.

1. Hold the switch in your hand and press the switch toggle lever into its spring loaded momentary position. You must install the switch so that the “spring loaded” end of the switch is oriented **DOWN** once the panel is installed in the boat.

IMPORTANT: The decal on the side of the switch with the arrow and the word “UP” refer to the position of the switch *when installed on the panel*.

2. Install jamb nut, and then locking washer, on switch threaded portion. Secure to panel using knurled nut. Tighten securely, to prevent switch from turning in hole. DO NOT overtighten.



a - Start Switch
b - Toggle Lever Spring Loaded Position (Direction of Movement DOWN When Installed)
c - Terminal Number(s)
d - Terminal(s)
e - Jamb Nut
f - Locking Washer

3. Follow instructions “a” and “b”. Refer to appropriate Wiring Diagram.

   a. Using screws provided, install wires to appropriate switch terminals as shown:

Harness Wire (Color Code)	CKT Number	Connect To:	Terminal Number
PURPLE (PPL)	36BC1	▶	2
PURPLE (PPL)	34DA	▶	1

   b. Make sure that all connections are secure. Seal terminals with Liquid Neoprene (92-25711).

WIRING THE INDICATOR LIGHTS

1. Follow instructions “a” - “d”. Refer to appropriate Wiring Diagram.

   a. Locate wire identification white tag titled “INDICATOR LAMPS”.

IMPORTANT: Be certain each bullet connection is properly seated and seal is not deformed after connecting.

2. Connect to individual lights as shown:

Harness Wire (Color Code)	CKT Number	Connect To:	Connection Location
YELLOW (YEL)	40D	▶	Black Wire tagged “CHK”
TAN (TAN)	118B	▶	Black Wire tagged “TEMP”
LIGHT BLUE (LTBLU)	117B	▶	Black Wire tagged “OIL”
GREEN (GRN)	109	▶	Black Wire tagged “BATT”
WHITE (WHT)	40BC	▶	Black Wire tagged “GLOW”

MOUNTING THE PANEL

1. Apply silicone sealing compound to contact surfaces on dashboard.
2. Install panel with the four screws provided, or those selected previously based on material and thickness of dashboard.

Relay Assembly (At Primary Station)

NOTE: *It may be necessary to remove Primary Station Engine System Monitor Panel to install the Relay Assembly, depending on boat configuration.*

1. Follow instructions “a” - “d”. Refer to appropriate Wiring Diagram.

   a. Disconnect existing PURPLE [PPL (CKT 34DA)] wire from the “I” terminal on key switch.

   b. Connect individual instrument harness wires and relay assembly wires as shown:

Relay Assembly Wire (Color Code)	CKT Number	Connect To:	Connection Location	CKT Number
PURPLE/ YELLOW (PPL/ YEL)	34D	▶	“I” terminal on key switch	Not Applicable
YELLOW/ RED (YEL/ RED)	12BA	▶	“I” terminal on key switch	
PURPLE (PPL)	12BB	▶	PURPLE (PPL) wire (previously at “I” terminal of key switch (See Note 1.)	34DA
BLACK	16H	▶	GREEN (GRN) [tagged “SPARE”] (See Note 1 and 2.)	110

Note 1.: Connect these wires together with screw and nut. Coat with Liquid Neoprene and slide rubber sleeve over connection.

Note 2.: Wire is sta-strapped to instrument harness near connector collar.

⚠ CAUTION

Avoid instrument malfunction and/or short circuits. Wires and wiring harnesses must not pull or hang on components to which they are connected. This could cause damage to the components and create a potential hazard.

c. Secure Primary Station Instrument Harness to bulkhead with cable clamps or wiring clips (not provided) as necessary to prevent harness(es) from pulling or hanging on components.

d. Secure relay assembly to bulkhead using suitable fastener or sta-strap relay assembly to harness.

Harness Connections

1. Follow instructions “a” – “d”. Refer to appropriate Wiring Diagram.

IMPORTANT: Connectors must be fully engaged and secure.

a. Connect “Y” Harness to Second Station instrument harness or extension harness.

b. Connect “Y” Harness to Primary Station instrument harness or extension harness.

c. Connect extension harness from engine to “Y” harness connector.

d. Secure harness(es) to boat at least every 18 in. (460 mm), using appropriate fasteners.

After Installation

1. Connect POSITIVE (+) battery cable (usually RED) to POSITIVE (+) battery terminal. Tighten clamp securely.
2. Connect NEGATIVE (–) battery cable (usually BLACK) to NEGATIVE (–) battery terminal. Tighten clamp securely.
3. Spray terminals with a battery connection sealant to help retard corrosion.
4. Upon first starting engine, check all indicator lights, instrument lights and instrumentation for proper function, at both primary and secondary stations.

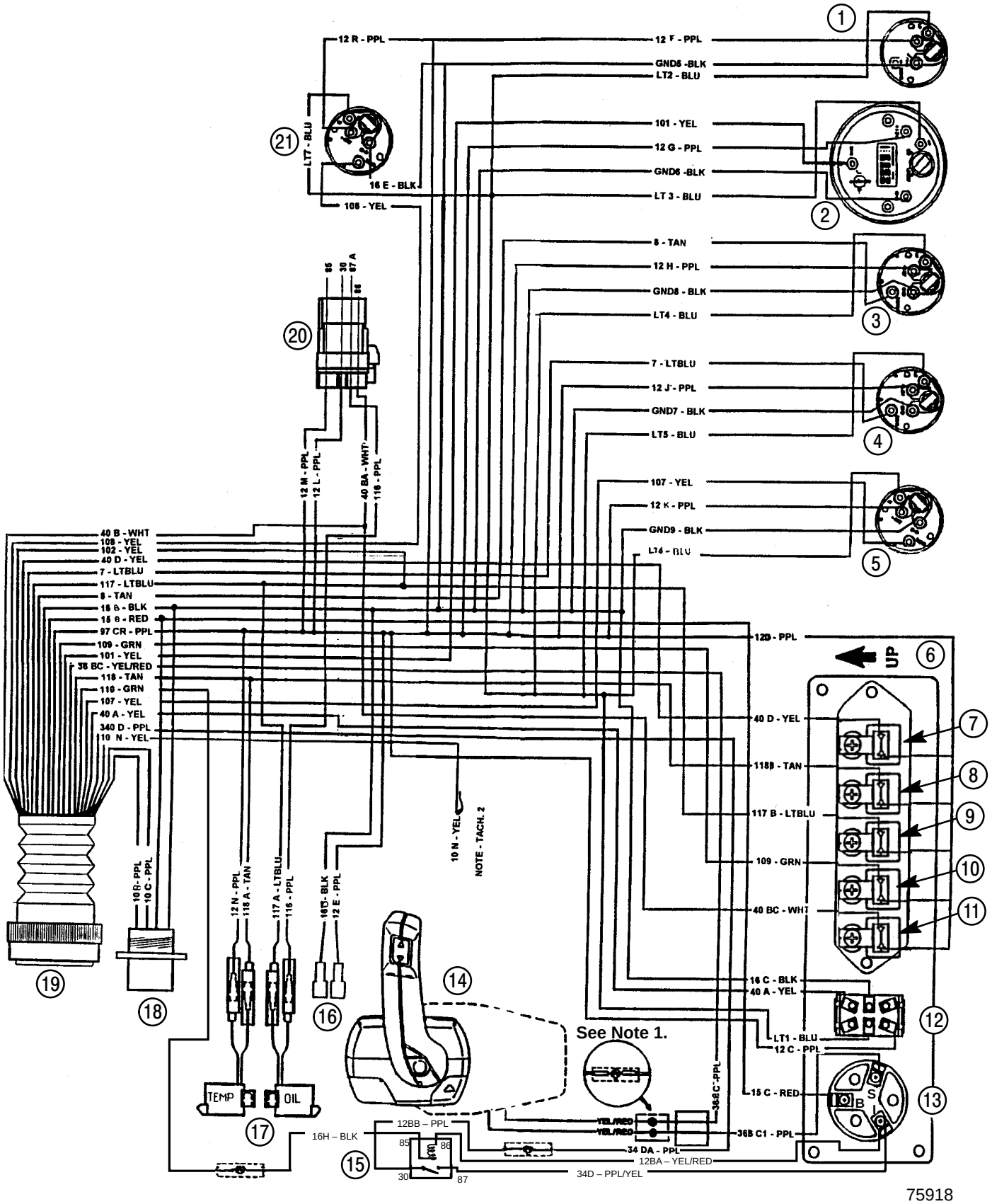
Wire Color Codes

The following color codes for wires are referenced in the Wiring Diagrams:

BLK = BLACK
BLU = BLUE
BRN = BROWN
GRY = GRAY
GRN = GREEN
ORN = ORANGE
PNK = PINK
PPL = PURPLE
RED = RED
TAN = TAN
WHT = WHITE
YEL = YELLOW
LT = LIGHT
DRK = DARK

Wiring Diagrams

PRIMARY STATION INSTRUMENTATION (WITH RELAY FOR SECOND STATION INSTALLED)

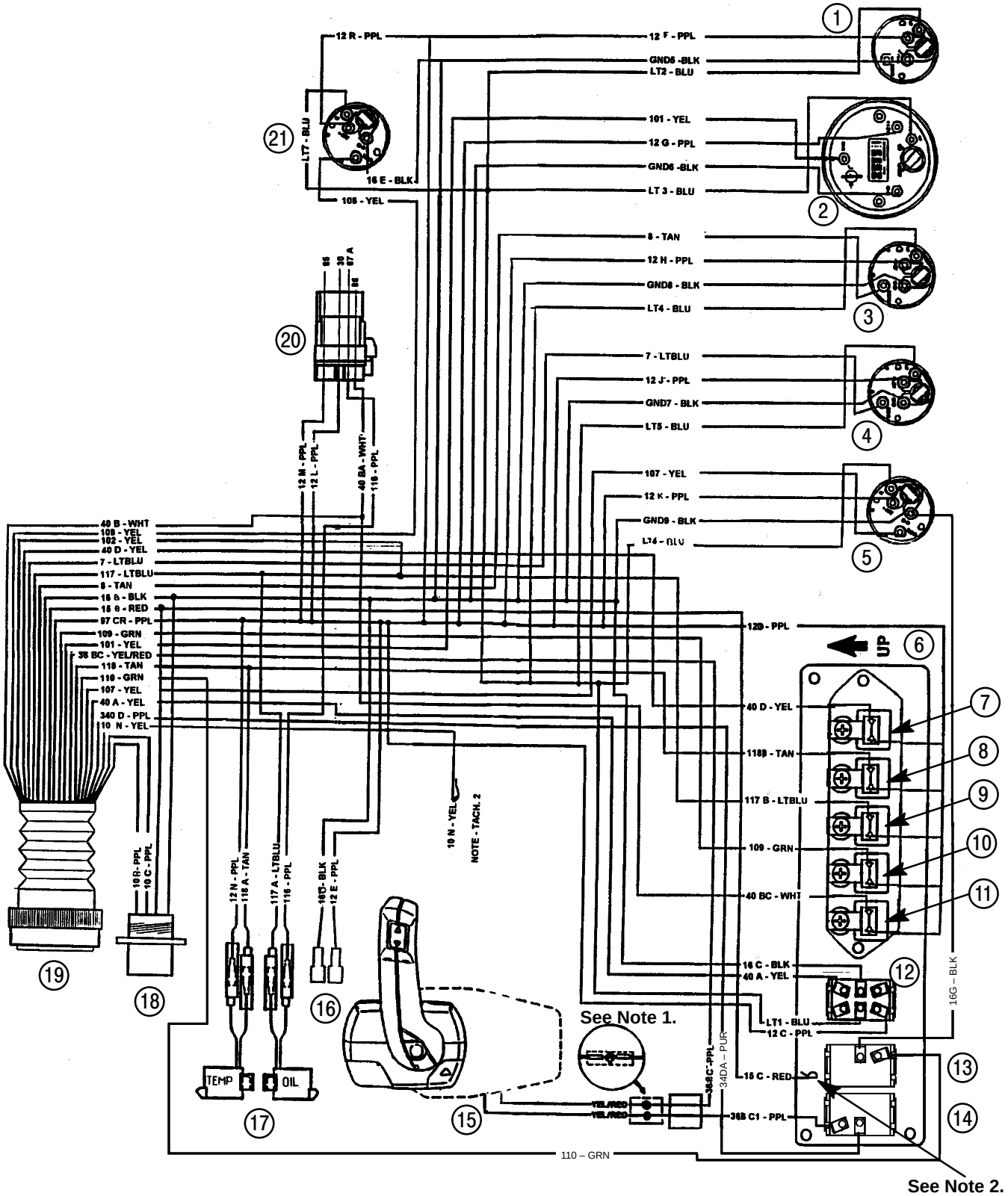


75918

1 - Voltmeter Gauge
2 - Tachometer Gauge
3 - Water Temperature Gauge
4 - Oil Pressure Gauge
5 - Trim Gauge
6 - Engine System Monitor Panel
7 - Check Engine Light
8 - Engine Coolant High Temperature/
Low Gear Lube Monitor Light
9 - Oil Pressure Warning Light
10- Charge Indicator Light
11- Preheat Indicator Light
12- Panel Lights/Audio Warning Test Switch
13- Key Switch
14- Neutral Start Safety Circuit/Remote Control
15- Second Station Relay (From Kit)
16- Hour Meter Gauge (Optional)
17- Audio Warning Horns
18- Diagnostic Tool Connection
19- Instrument Harness Connector
20- Wait-To-Start Relay
21- Fuel Gauge (Optional)

Note 1: Connect these wires together with a screw and nut. Coat with Liquid Neoprene and slide rubber sleeve over connection.

Second Station Instrumentation



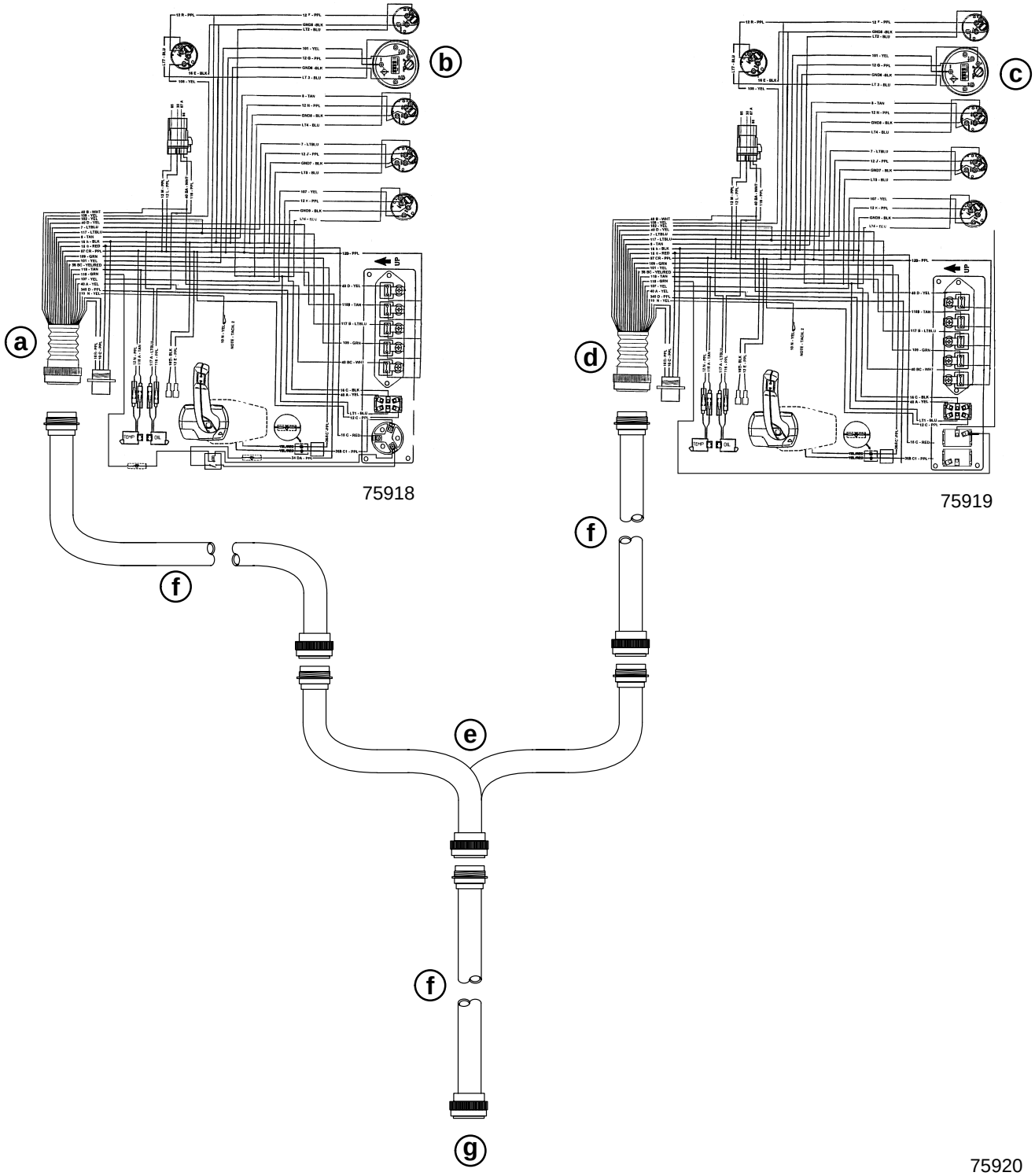
75919

1 - Voltmeter Gauge
2 - Tachometer Gauge
3 - Water Temperature Gauge
4 - Oil Pressure Gauge
5 - Trim Gauge
6 - Engine System Monitor Panel
7 - Check Engine Light
8 - Engine Coolant High Temperature/
Low Gear Lube Monitor Light
9 - Oil Pressure Warning Light
10- Charge Indicator Light
11- Preheat Indicator Light
12- Panel Lights/Audio Warning Test Switch
13- Stop Switch
14- Start Switch
15- Neutral Start Safety Circuit/Remote Control
16- Hour Meter Gauge (Optional)
17- Audio Warning Horns
18- Diagnostic Tool Connection
19- Instrument Harness Connector
20- Wait-To-Start Relay
21- Fuel Gauge (Optional)

Note 1: Connect these wires together with a screw and nut. Coat with Liquid Neoprene and slide rubber sleeve over connection.

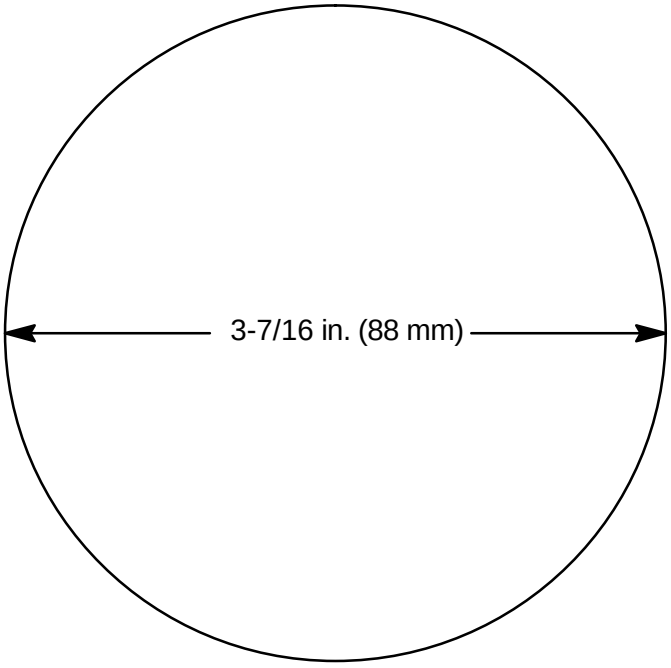
Note 2: Wire not used. Tape wire end with at least two layers of electrical tape and tape back.

Wiring Harness Connections



a - Primary Station Instrument Harness
b - Primary Station Instrumentation
c - Second Station Instrumentation
d - Second Station Instrument Harness
e - “Y”- Harness
f - Extension Harness
g - To Engine

Template



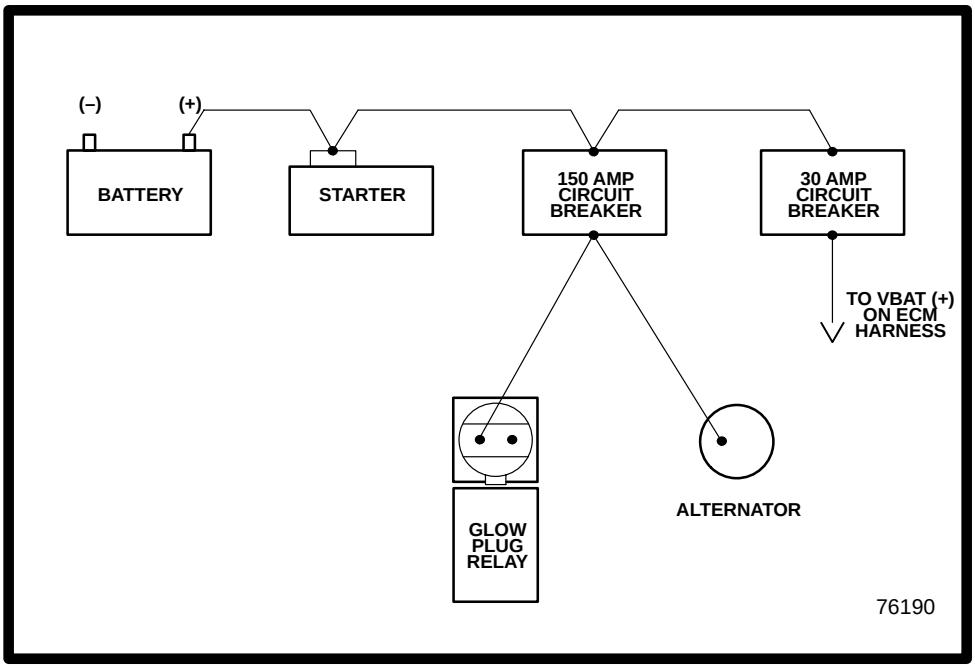
Drilling Hole Template for Quicksilver Tachometer

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ELECTRICAL SYSTEMS

4

E



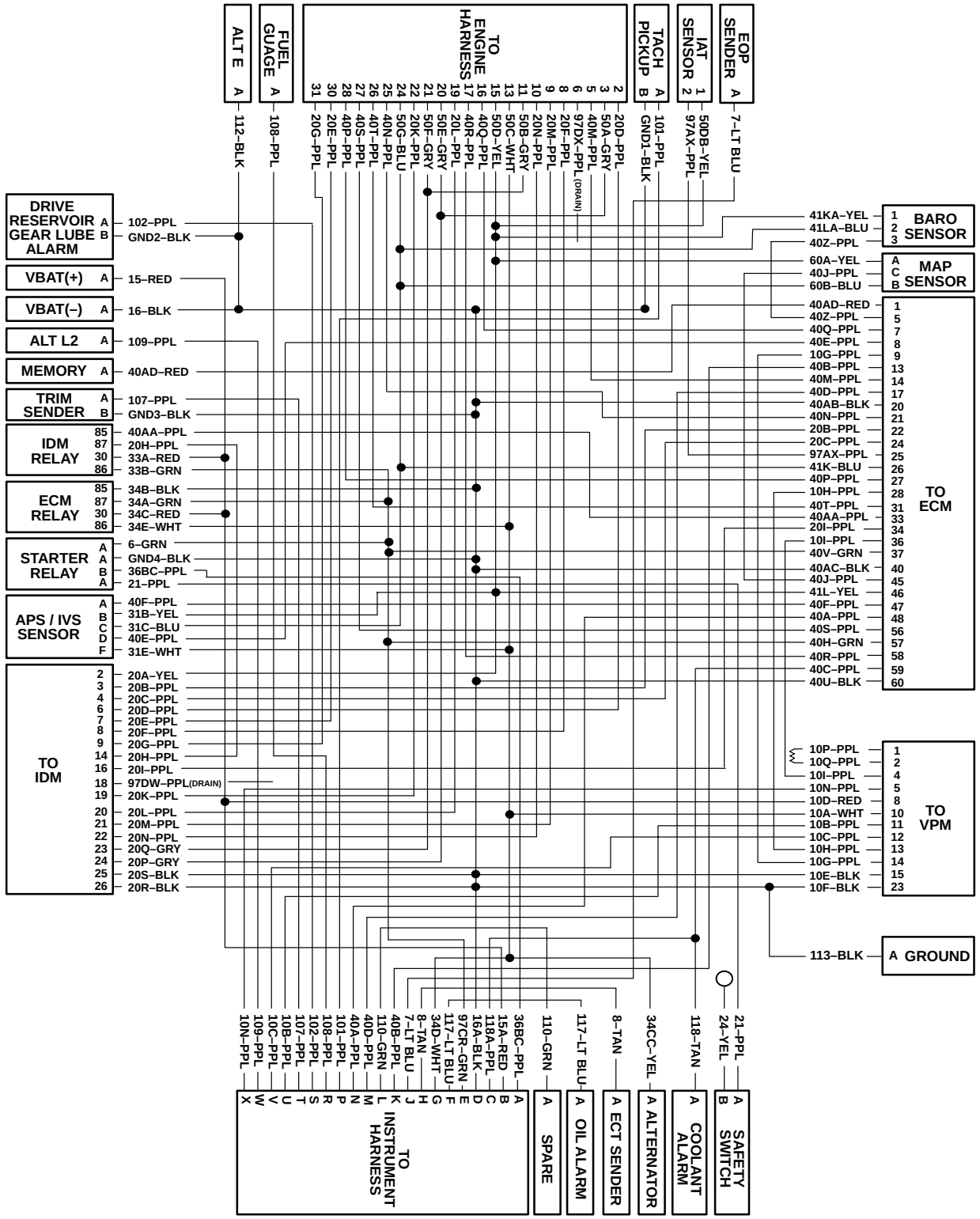
WIRING DIAGRAMS

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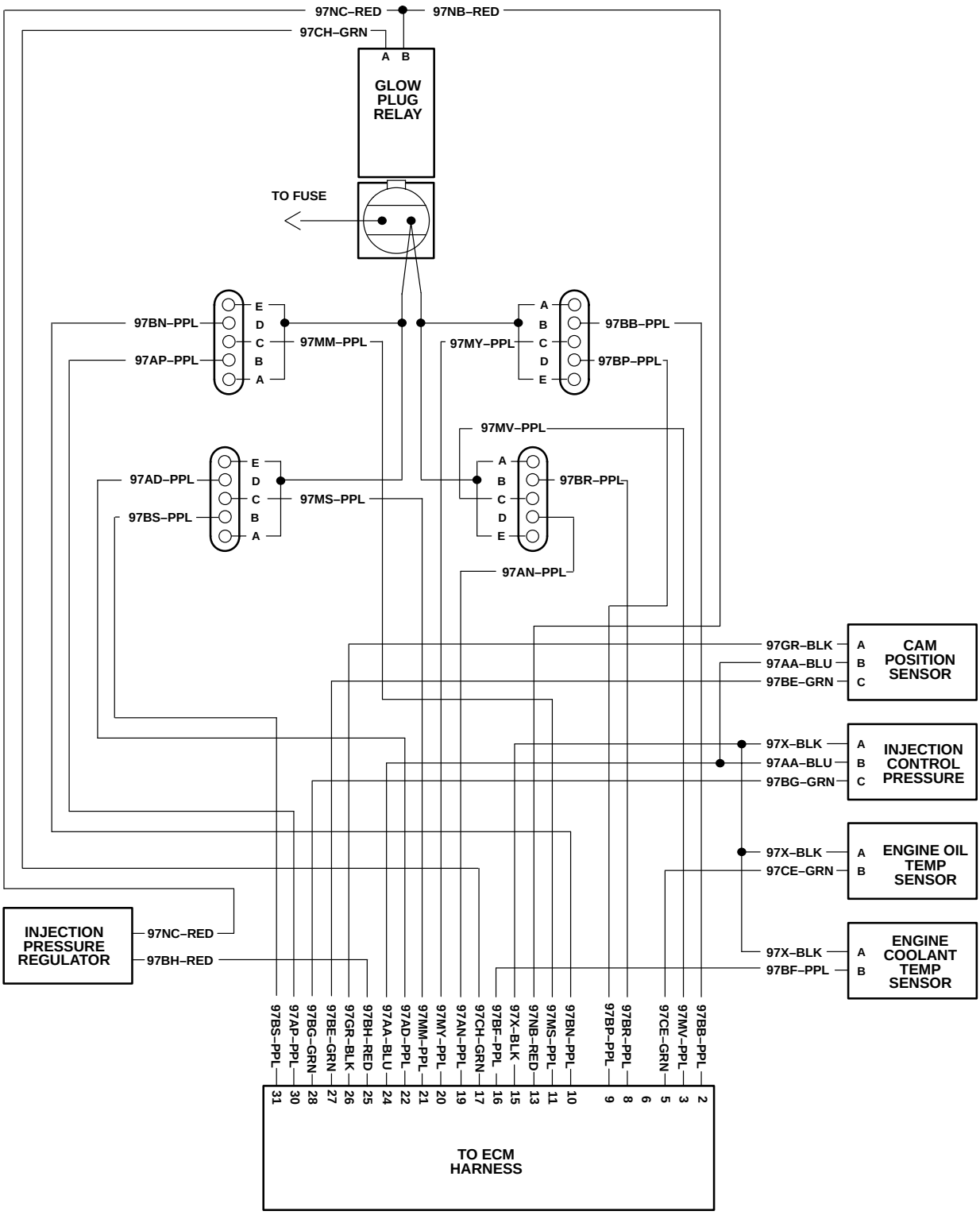
Wiring Diagrams

ECM System Harness



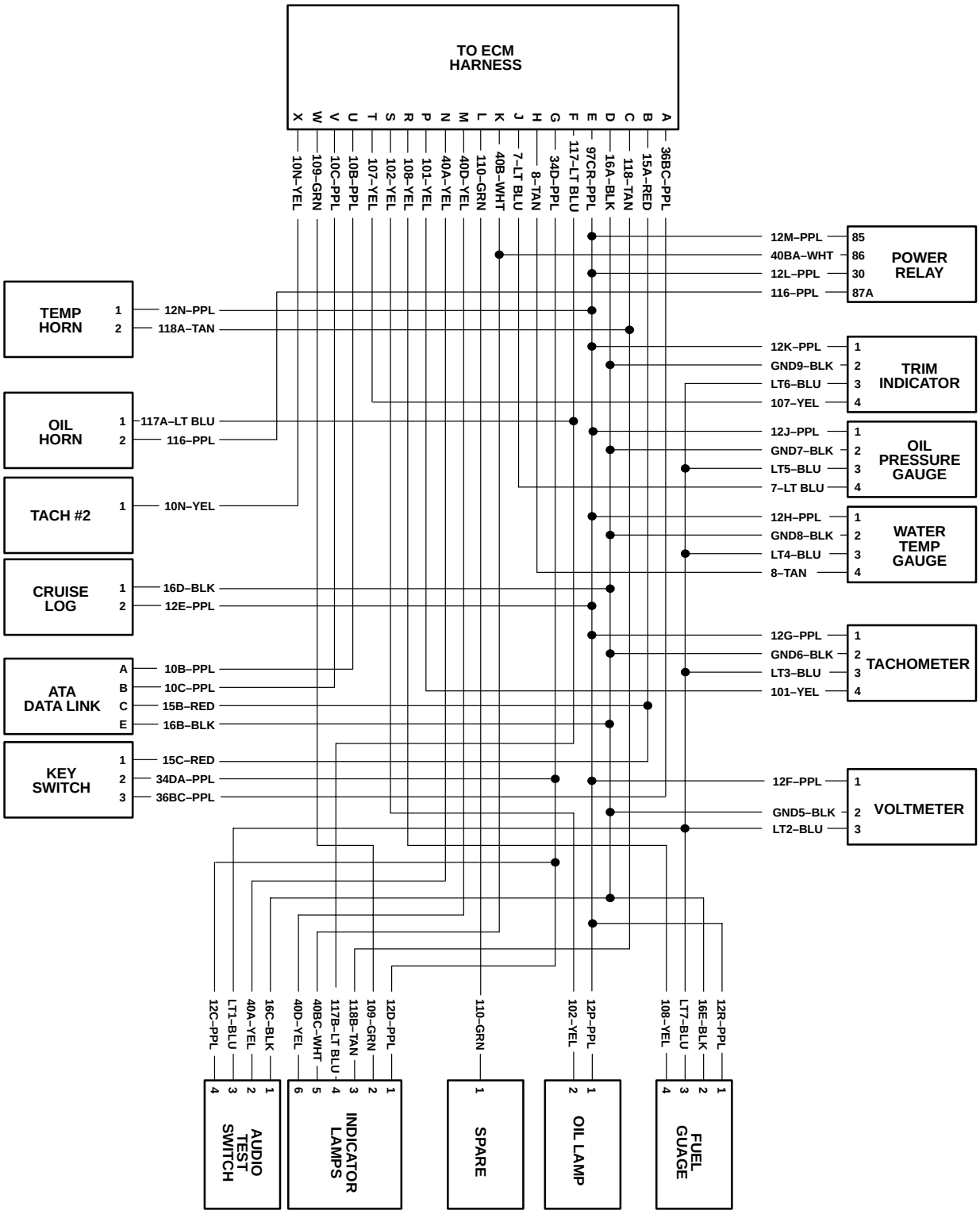
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Engine Harness



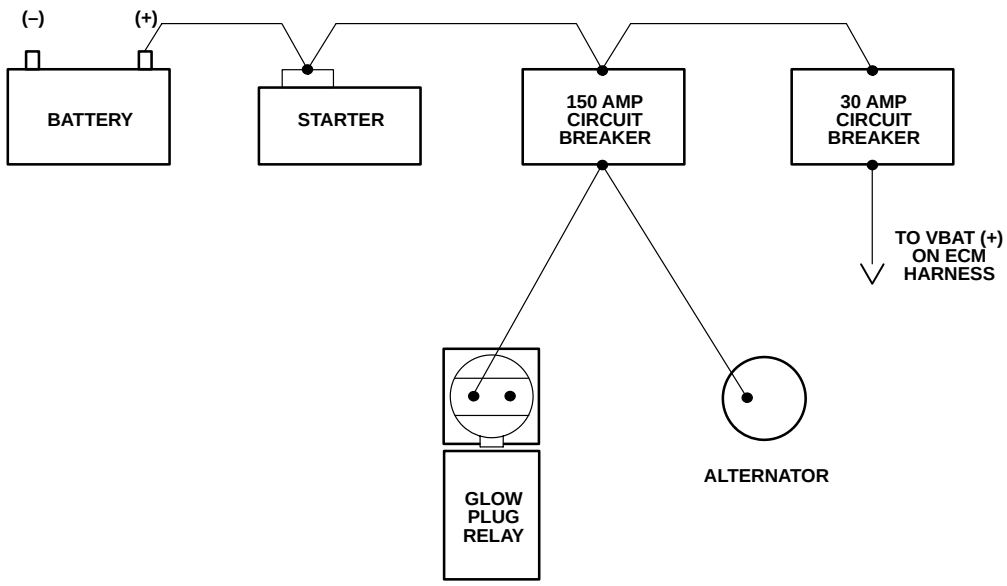
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Instrument Harness



76189

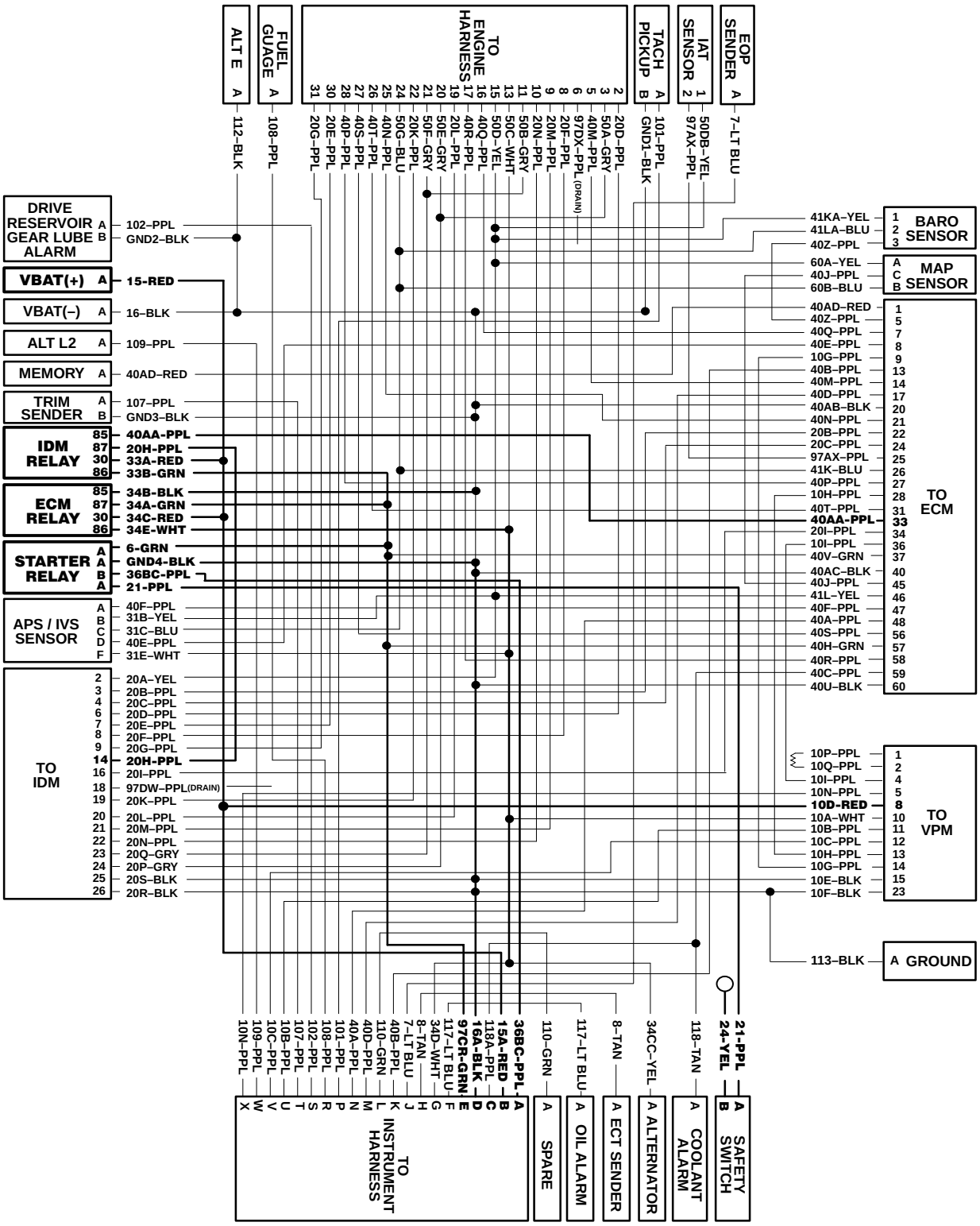
Circuit Breakers and Power Circuits



76190

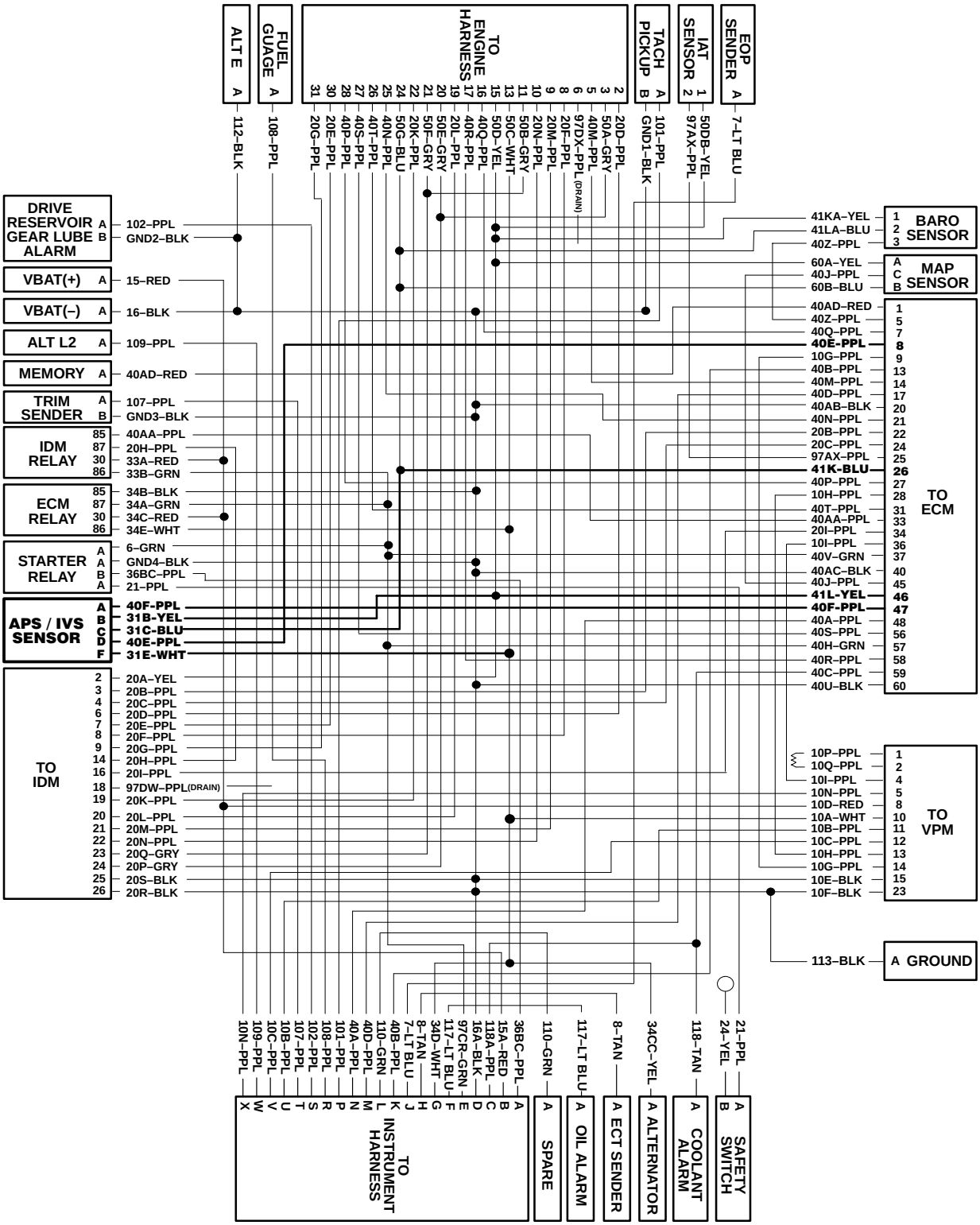
Circuit Diagrams

Relay and Power Circuits



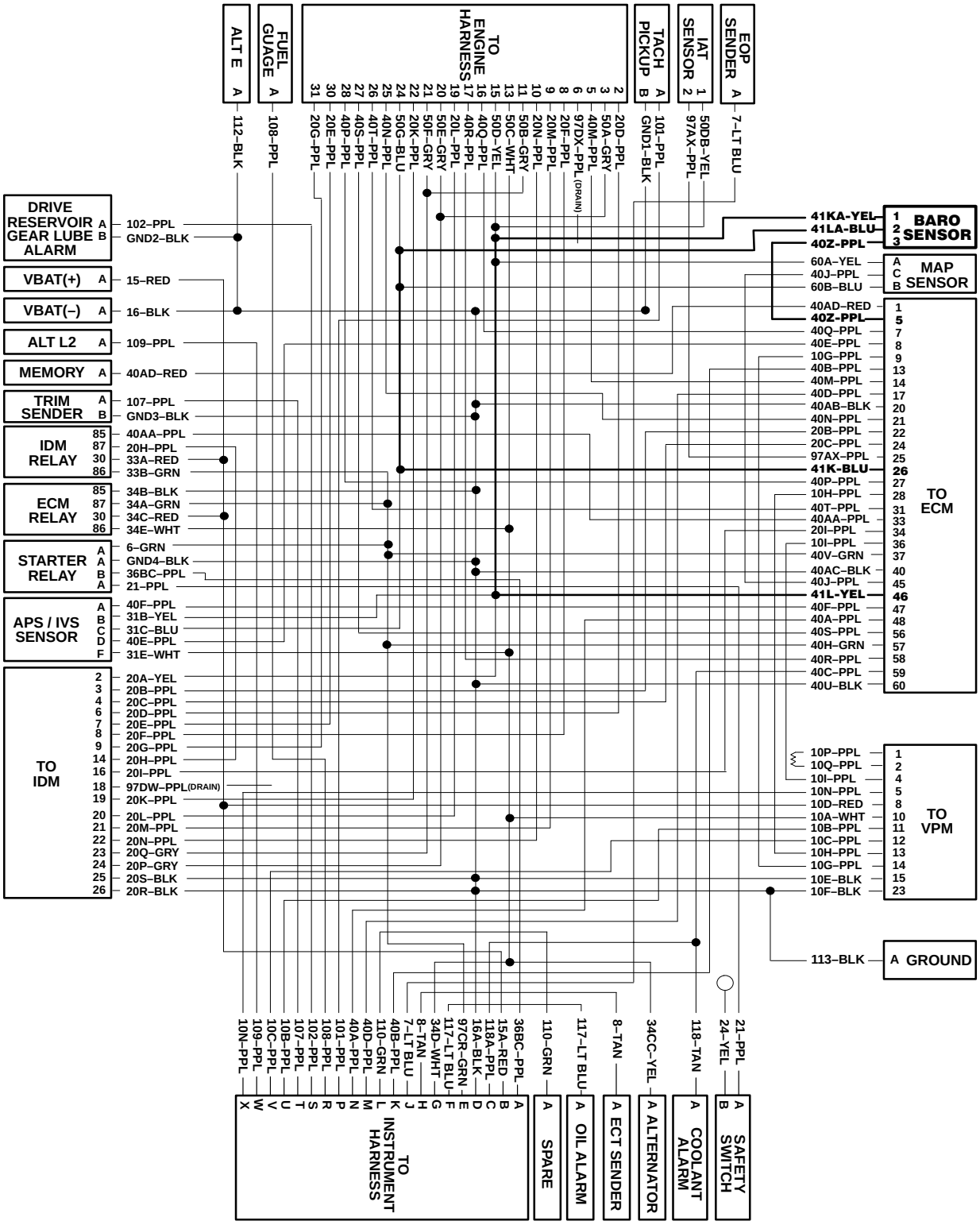
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APS/IVS Circuits



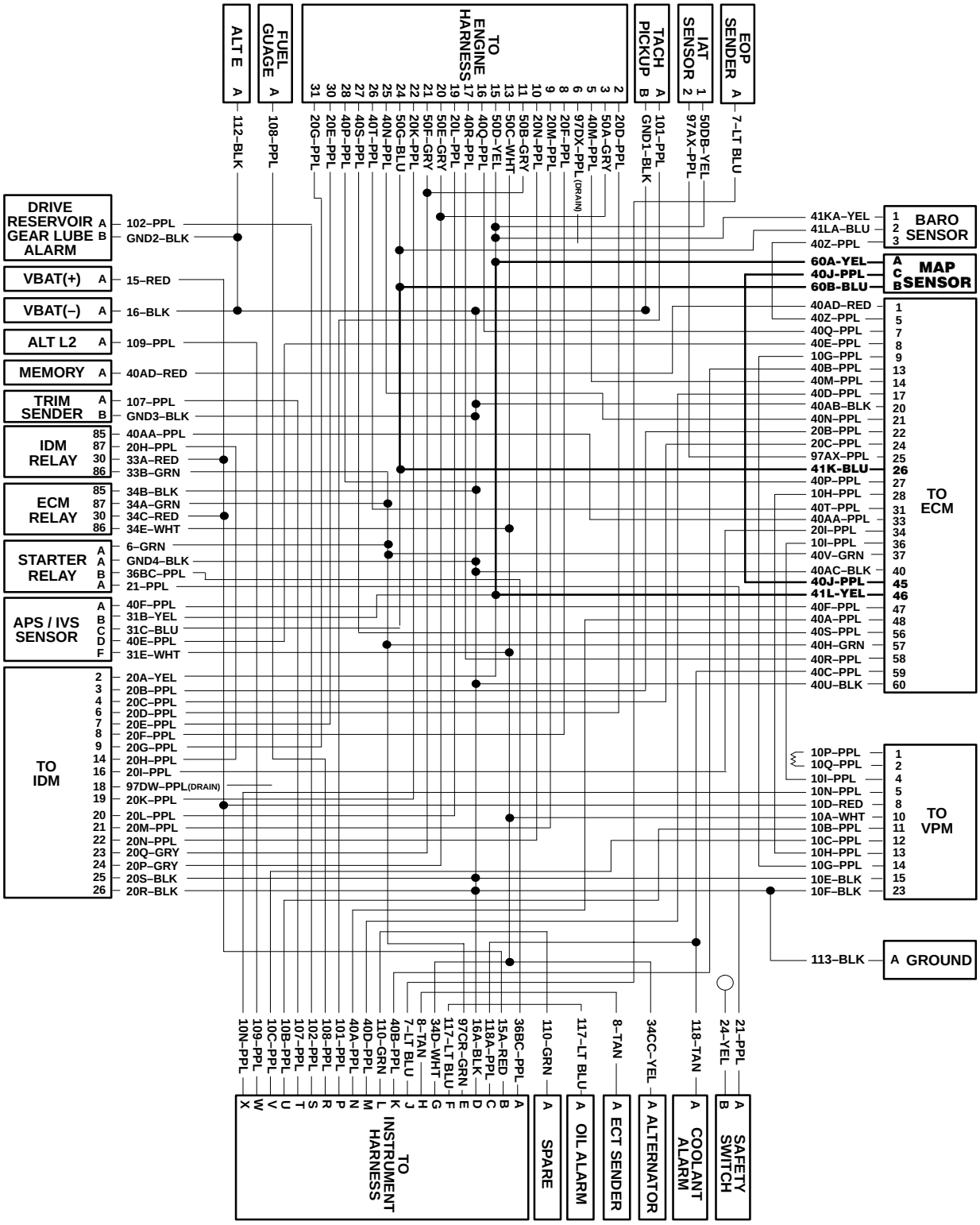
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BARO Circuit



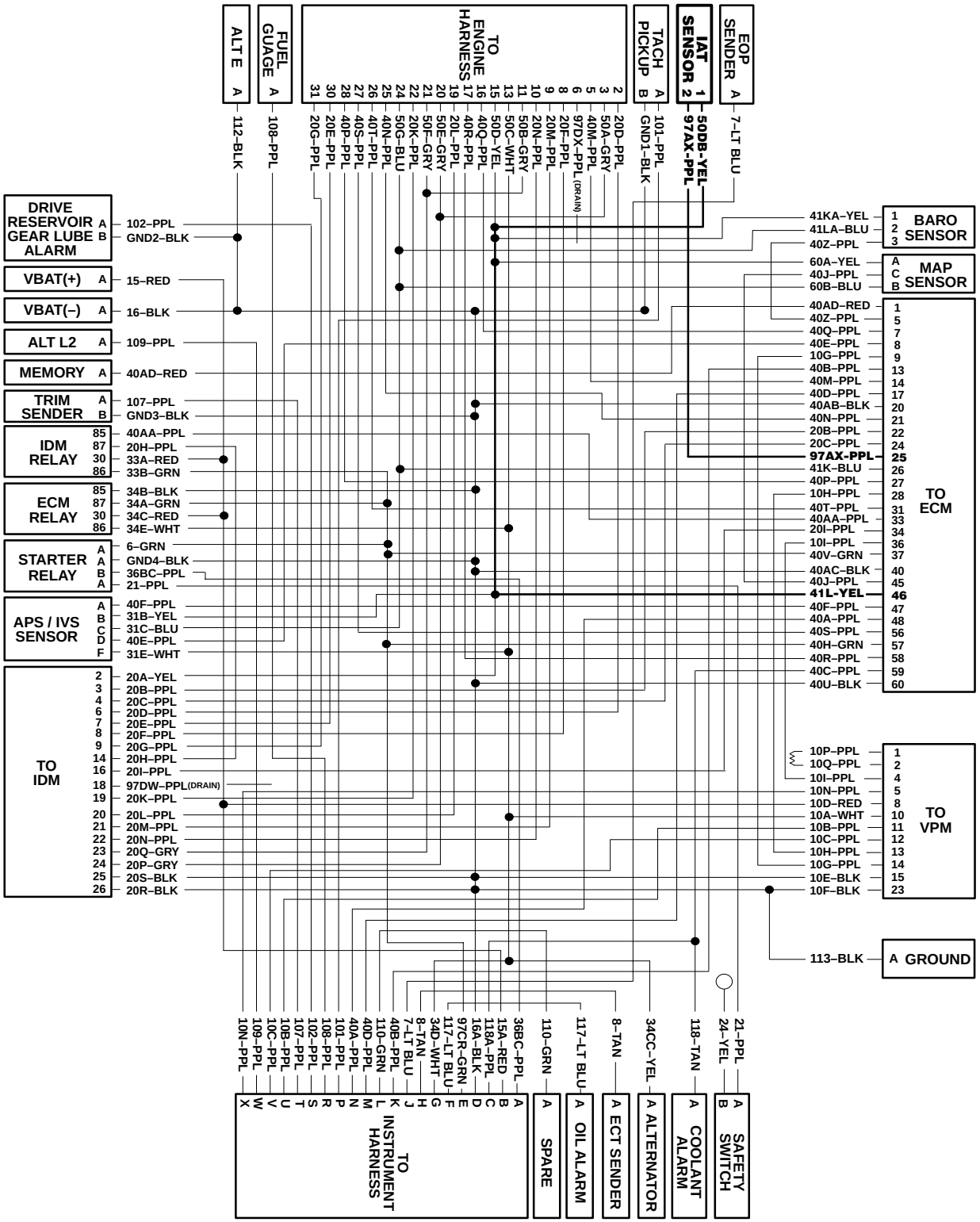
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MAP Circuit



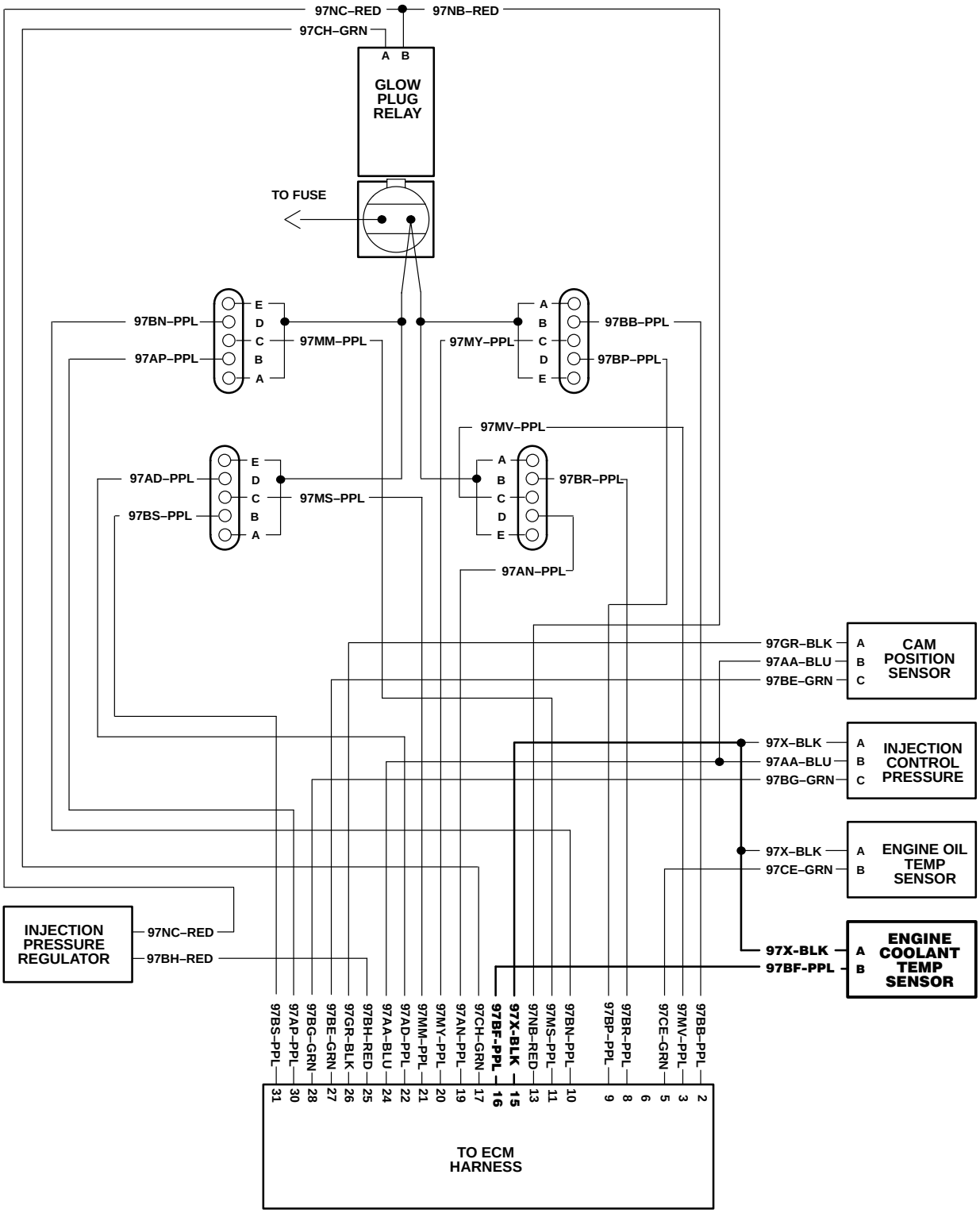
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IAT Circuit



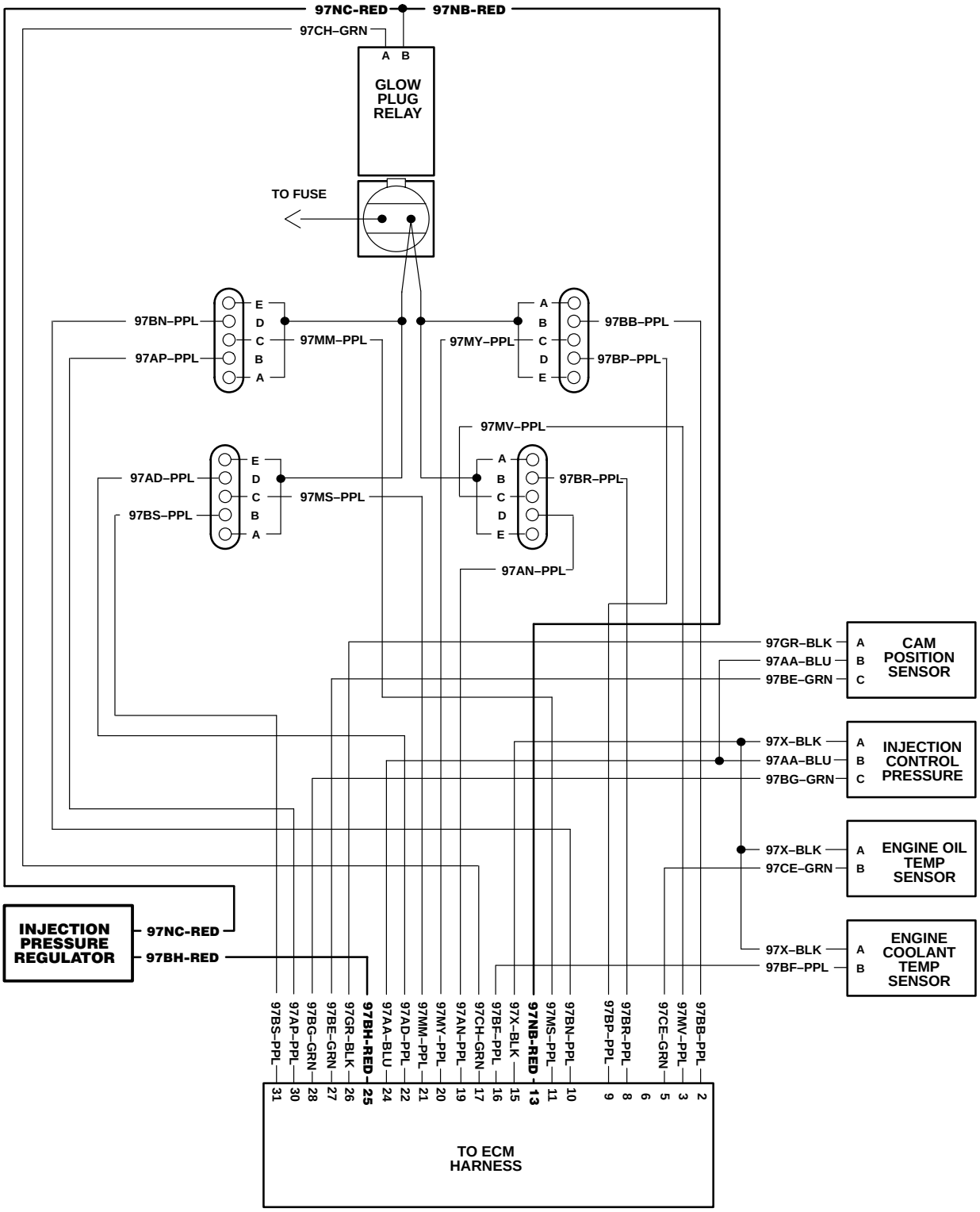
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ECT Circuit



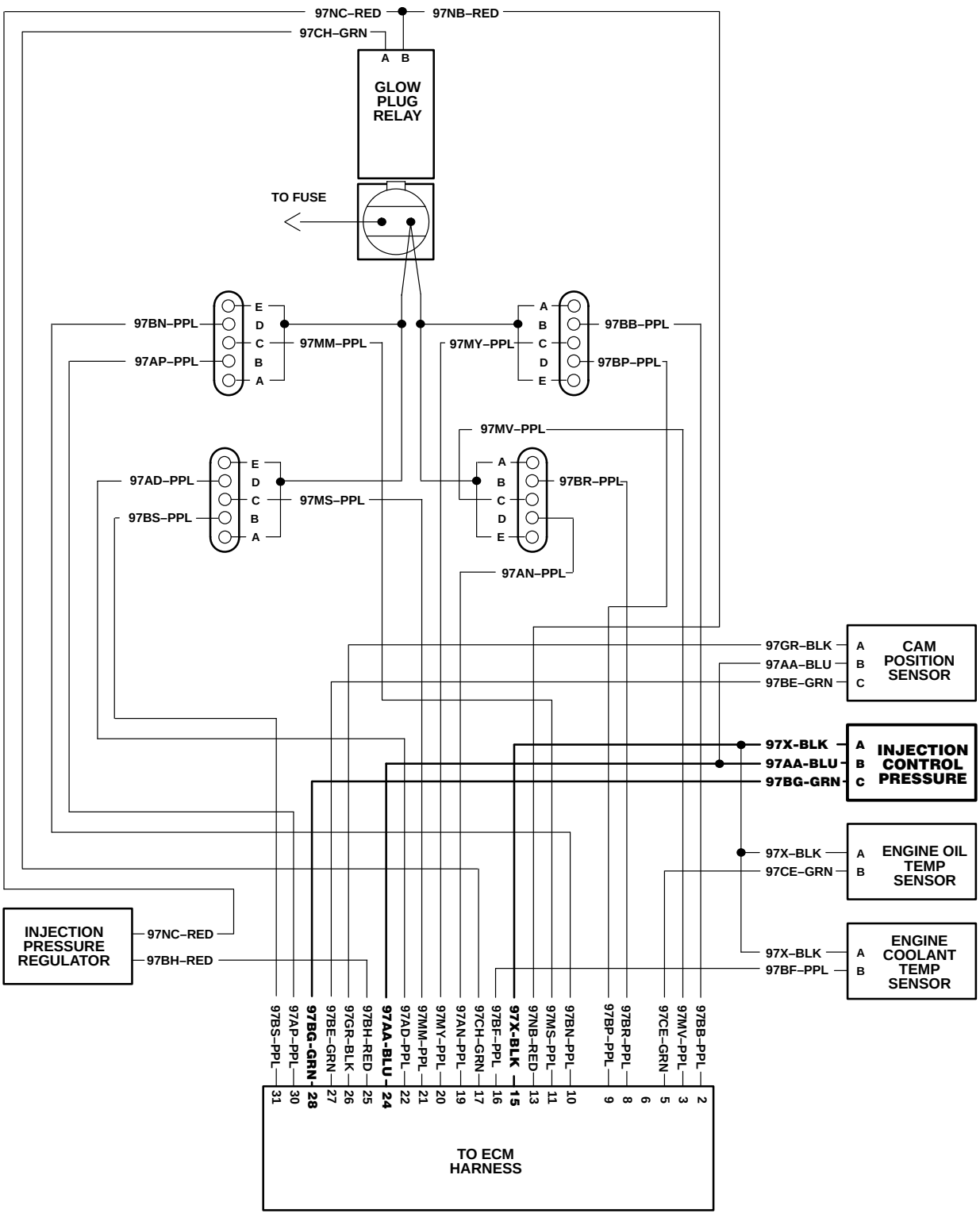
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IPR Circuit



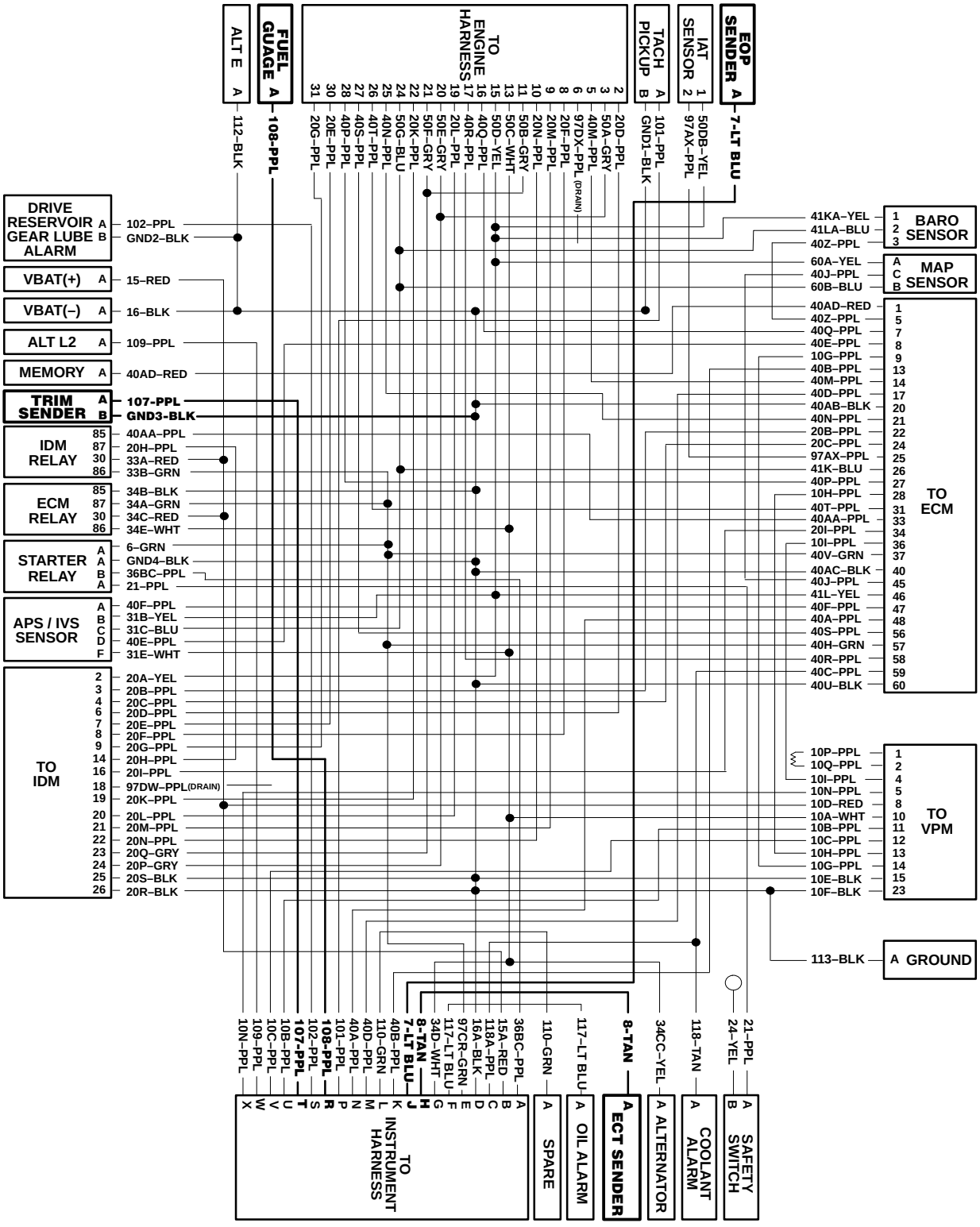
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ICP Circuit



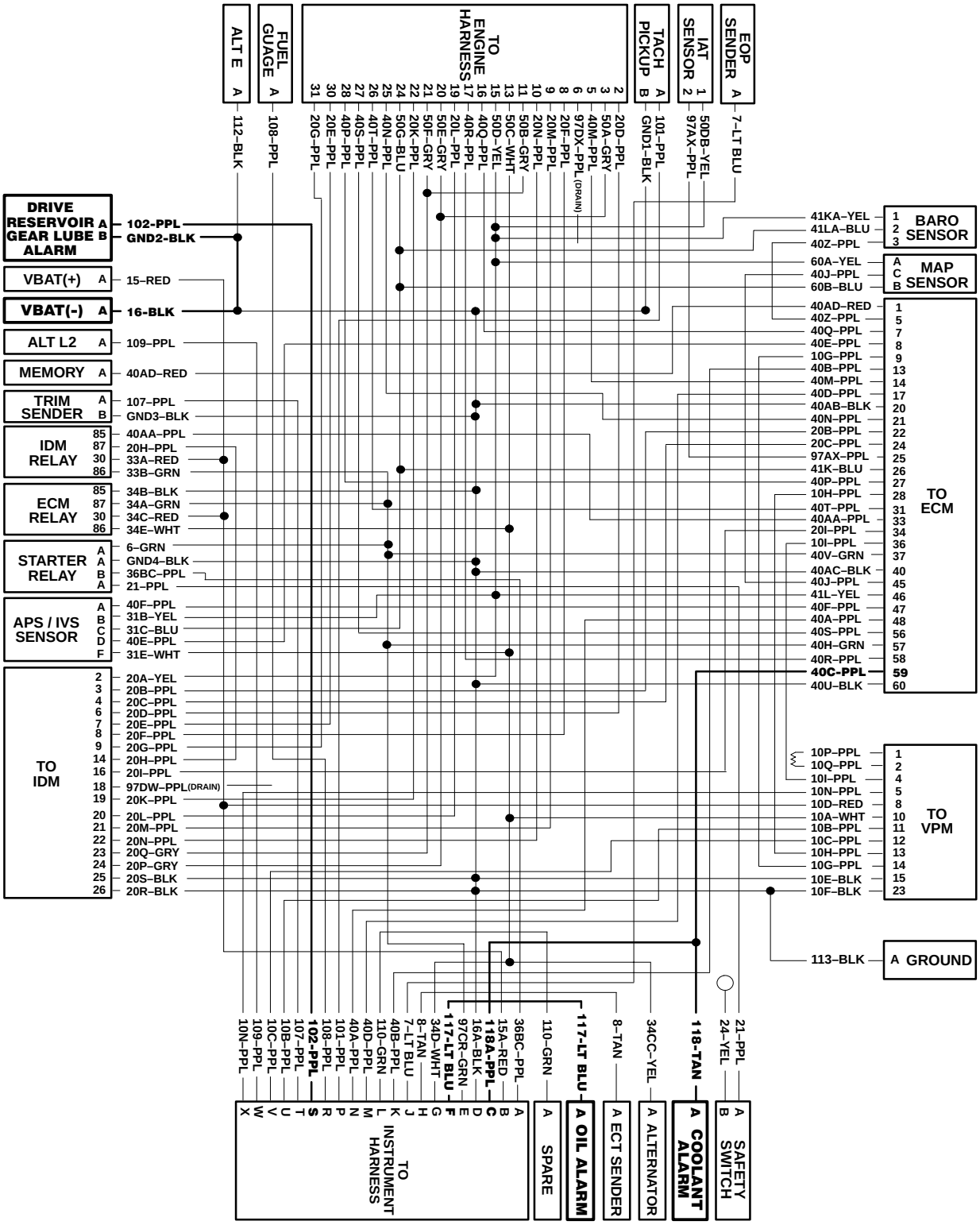
76195

Gauge Circuits


ALT E A
FUEL GUAGE A
TO ENGINE HARNESS
TACH PICKUP B A
IAT SENSOR 1 2
EOP SENDER A
112–BLK
108–PPL
7–LT BLU
DRIVE RESERVOIR GEAR LUBE ALARM A B 102–PPL GND2–BLK
VBAT(+) A 15–RED
VBAT(–) A 16–BLK
ALT L2 A 109–PPL
MEMORY A 40AD–RED
TRIM SENDER A B 107–PPL GND3–BLK
IDM RELAY 85 87 30 86 40AA–PPL 20H–PPL 33A–RED 33B–GRN
ECM RELAY 85 87 30 86 34B–BLK 34A–GRN 34C–RED 34E–WHT
STARTER RELAY A A B A 6–GRN GND4–BLK 36BC–PPL 21–PPL
APS / IVS SENSOR A B C D E F 40F–PPL 31B–YEL 31C–BLU 40E–PPL 31E–WHT
TO IDM 2 3 4 6 7 8 9 14 16 18 19 20 21 22 23 24 25 26 20A–YEL 20B–PPL 20C–PPL 20D–PPL 20E–PPL 20F–PPL 20G–PPL 20H–PPL 20I–PPL 97DW–PPL (DRAIN) 20K–PPL 20L–PPL 20M–PPL 20N–PPL 20Q–GRY 20P–GRY 20S–BLK 20R–BLK
BARO SENSOR 1 2 3 41KA–YEL 41LA–BLU 40Z–PPL
MAP SENSOR A C B 60A–YEL 40J–PPL 60B–BLU
TO ECM 1 5 7 8 9 13 14 17 20 21 22 24 25 26 27 28 31 33 34 36 37 40 45 46 47 48 56 57 58 59 60 40AD–RED 40Z–PPL 40Q–PPL 40E–PPL 10G–PPL 40B–PPL 40M–PPL 40D–PPL 40AB–BLK 40N–PPL 20B–PPL 20C–PPL 97AX–PPL 41K–BLU 40P–PPL 10H–PPL 40T–PPL 40AA–PPL 20I–PPL 10I–PPL 40V–GRN 40AC–BLK 40J–PPL 41L–YEL 40F–PPL 40A–PPL 40S–PPL 40H–GRN 40R–PPL 40C–PPL 40U–BLK
TO VPM 1 2 4 5 8 10 11 12 13 14 15 23 10P–PPL 10Q–PPL 10I–PPL 10N–PPL 10D–RED 10A–WHT 10B–PPL 10C–PPL 10H–PPL 10G–PPL 10E–BLK 10F–BLK
A GROUND 113–BLK
TO INSTRUMENT HARNESS
A ECT SENDER 8–TAN
A SPARE 110–GRN
A OIL ALARM 117–LT BLU
A ALTERNATOR 34CC–YEL
A COOLANT ALARM 118–TAN
A B SAFETY SWITCH 24–YEL 21–PPL

76197

Alarm Circuits

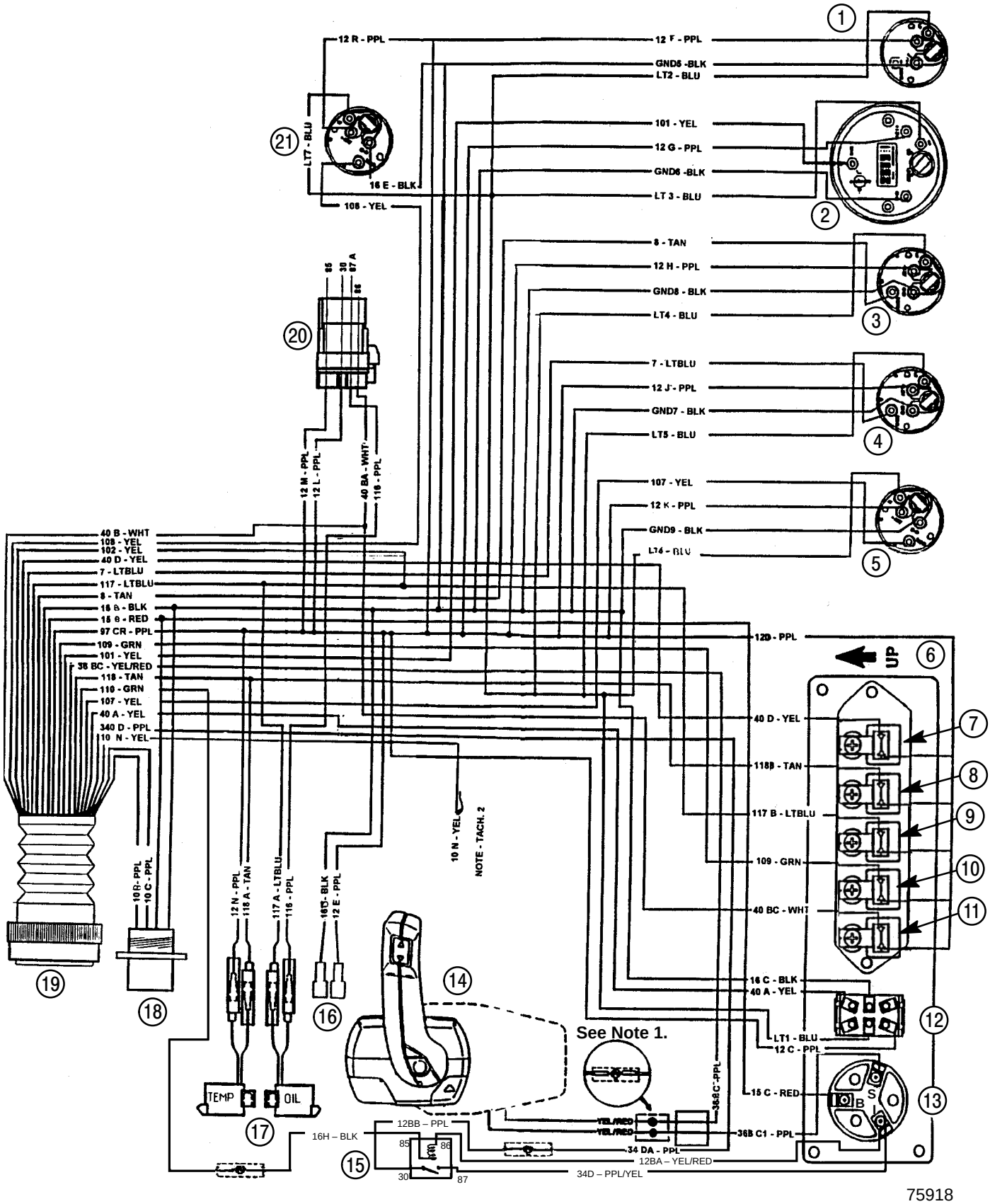


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Instrument Panel Wiring Diagrams

Primary Station Instrumentation (With Relay for Second Station Installed)

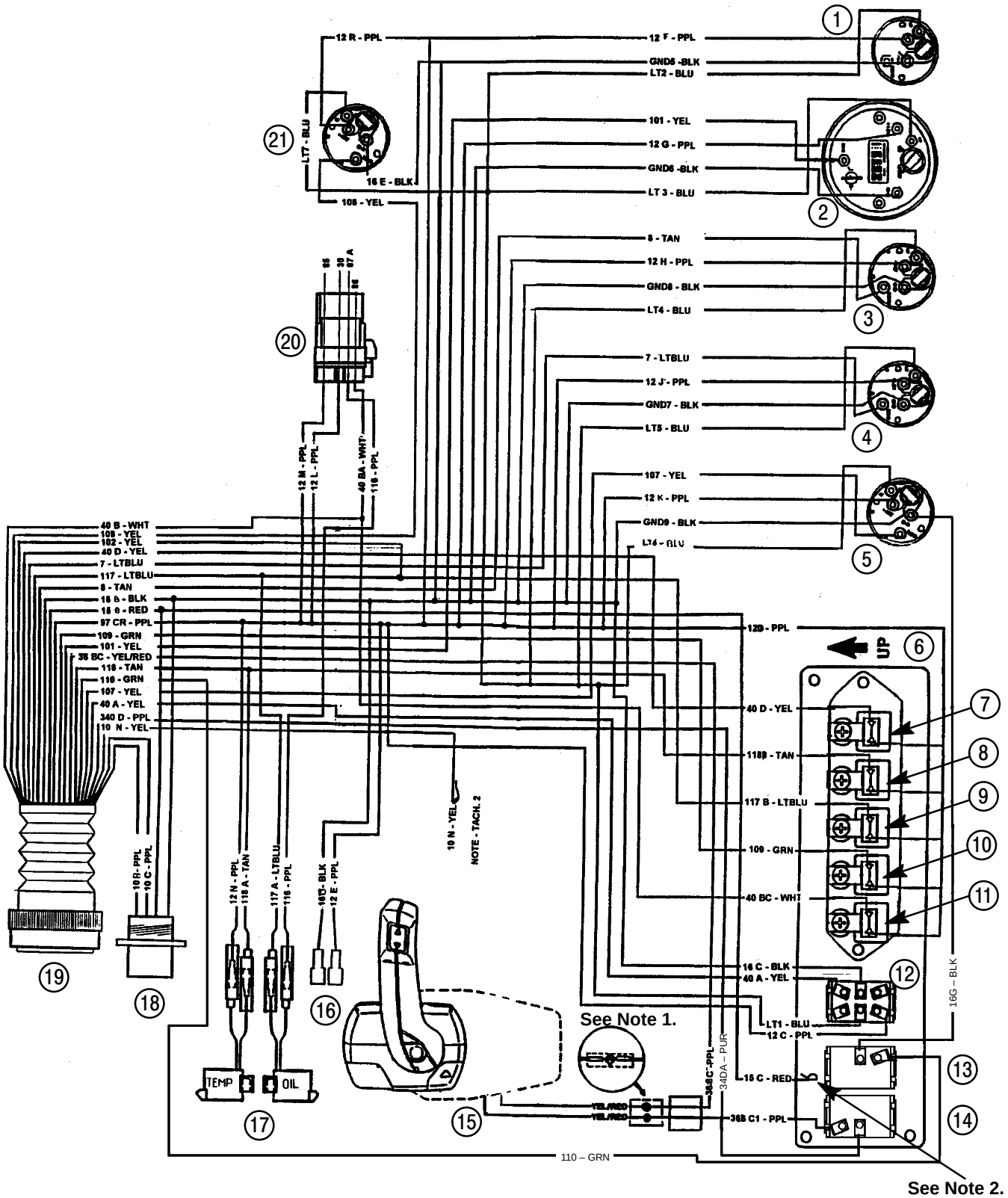


75918

1 - Voltmeter Gauge
2 - Tachometer Gauge
3 - Water Temperature Gauge
4 - Oil Pressure Gauge
5 - Trim Gauge
6 - Engine System Monitor Panel
7 - Check Engine Light
8 - Engine Coolant High Temperature/
Low Gear Lube Monitor Light
9 - Oil Pressure Warning Light
10- Charge Indicator Light
11- Preheat Indicator Light
12- Panel Lights/Audio Warning Test Switch
13- Key Switch
14- Neutral Start Safety Circuit/Remote Control
15- Second Station Relay (From Kit)
16- Hour Meter Gauge (Optional)
17- Audio Warning Horns
18- Diagnostic Tool Connection
19- Instrument Harness Connector
20- Wait-To-Start Relay
21- Fuel Gauge (Optional)

Note 1: Connect these wires together with a screw and nut. Coat with Liquid Neoprene and slide rubber sleeve over connection.

Second Station Instrumentation



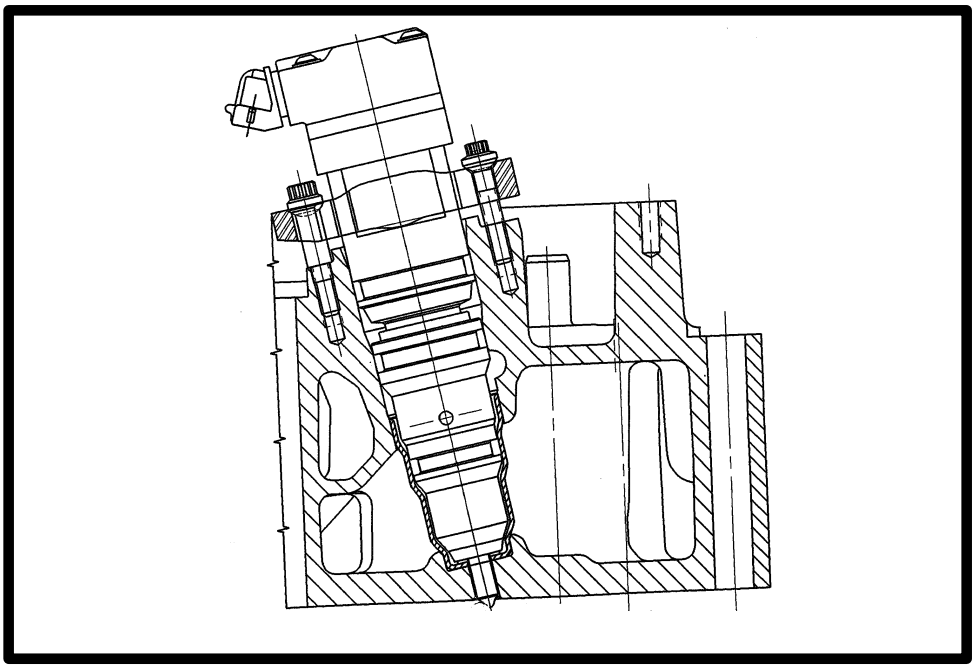
75919

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Note 1: Connect these wires together with a screw and nut. Coat with Liquid Neoprene and slide rubber sleeve over connection.

Note 2: Wire not used. Tape wire end with at least two layers of electrical tape and tape back.

FUEL SYSTEM



5

A

ENGINE CONTROL SYSTEM OVERVIEW

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Fuel Supply System

Fuel System Description

The fuel system consists of three major sub-systems:

- Fuel Supply System.
- Injection Control Pressure System.
- Fuel Injector.

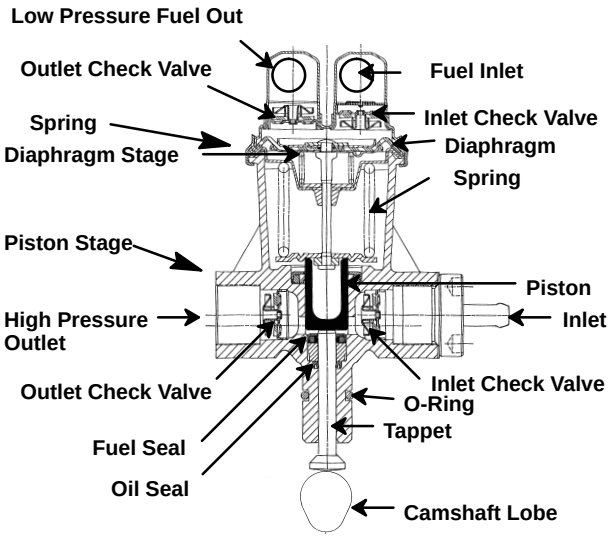
These subsystems work together to inject pressurized fuel into the combustion chambers. The function of the fuel supply system is to deliver fuel to the injectors. The injection control pressure system supplies the injectors with high pressure lube oil. The fuel injectors use the pressure from the lube oil to pressurize the fuel and inject the fuel into the combustion chambers.

The function of the fuel supply system is to deliver fuel from the fuel tank(s) to the injectors. The components involved in this task are:

- Fuel Lines
- Fuel Strainer
- Transfer Fuel Pump
- Fuel Filter/Water Separator
- Fuel Pressure Regulator Valve

Fuel Supply Pump

The fuel transfer pump on the engine is a camshaft driven two stage diaphragm/piston pump mounted in the engine “V”.



Fuel System Operation

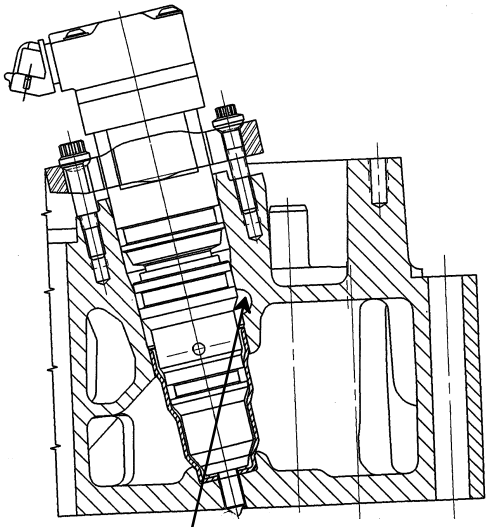
The diaphragm stage of the tandem lift pump draws fuel from the tank. Pressurized fuel 4 to 6 psi (28 to 41 kPa) from the diaphragm stage is supplied to the fuel filter.

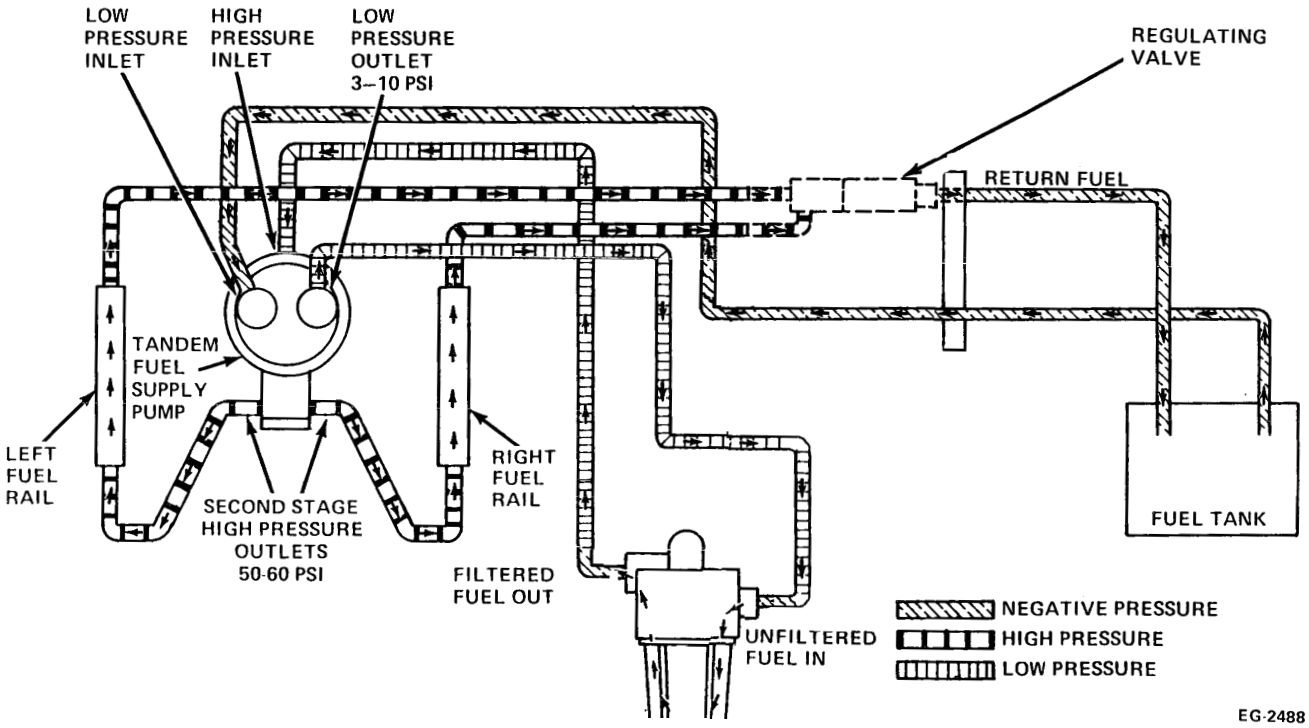
Fuel in the filter housing passes through the filter element to a standpipe in the center of the filter assembly. Clean fuel is then routed to the inlet of the piston stage of the tandem pump.

The piston stage of the tandem pump raises fuel pressure from 4 psi to 40 psi (28 to 276 kPa) to insure proper filling of the injectors. Fuel from this stage is divided through steel lines to the back of each cylinder head. These lines supply fuel to a gallery drilled in each cylinder head which intersects each injector bore in the cylinder head.

Return fuel from the two fuel galleries is routed through hoses, of a special rubber compound, from the front of each head to the pressure regulator. These hoses provide flexibility in the fuel system by absorbing and smoothing pressure pulses from the piston stage of the pump.

The pressure regulator contains a spring loaded valve to control pressure in the fuel galleries to 40 psi (276 kPa). Return fuel flows through the regulator and is routed to the fuel tank(s).





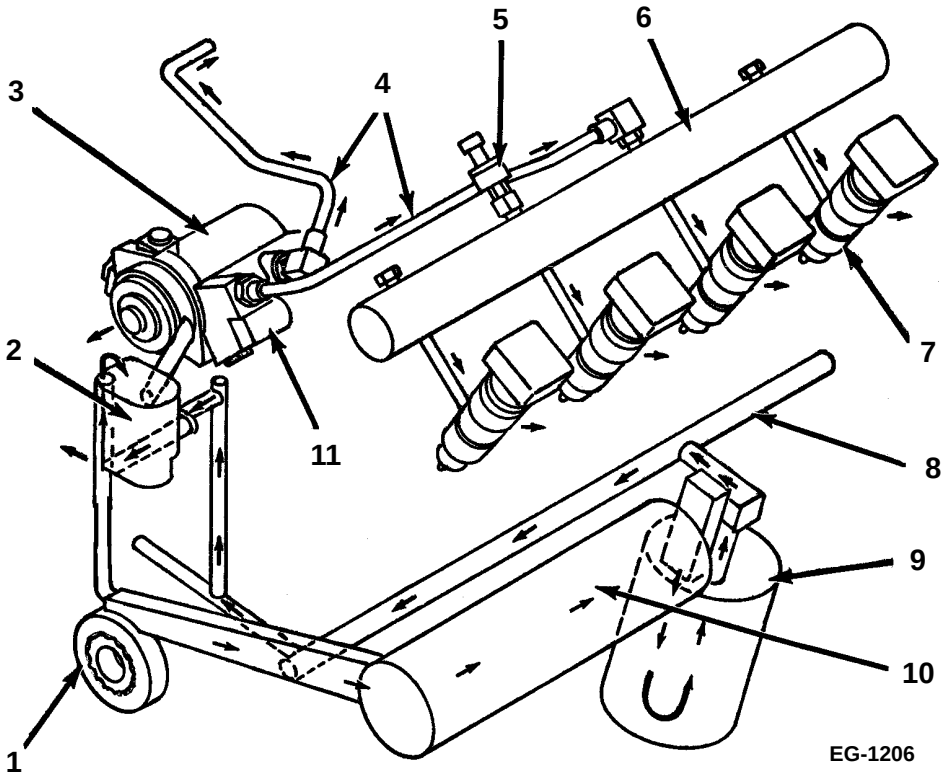
Injection Control Pressure System

Pressure System Operation

The system utilizes a hydraulically actuated injector to pressurize fuel inside the injector. The hydraulic fluid used to actuate the injector is engine oil.

Oil is drawn from the oil pan thru the pickup tube by the engine oil pump. The engine oil pump is a gerotor type pump driven by the crankshaft. Oil is fed through passages in the front cover to an oil reservoir mounted on top of the front cover.

The reservoir makes available a constant supply of oil to a high pressure hydraulic pump mounted in the engine “V“. The high pressure pump is a gear driven seven plunger swash plate pump. High pressure oil is delivered by the high pressure pump to oil galleries machined into the cylinder heads, drilled intersecting passages supply high pressure oil to the injector.

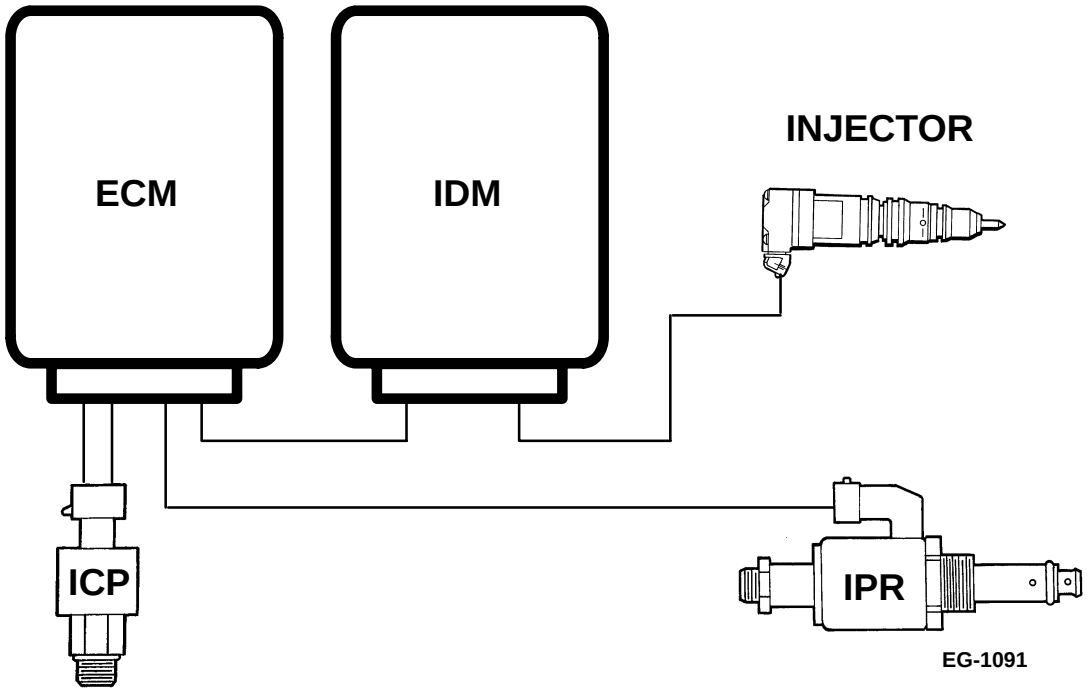


1 - Oil Pump
2 - Reservoir (Located On Top of Front Cover)
3 - High Pressure Pump
4 - High Pressure Hoses
5 - Injection Control Pressure Sensor
6 - Cylinder Head High Pressure Rail
7 - Injector (8)
8 - Gallery (Crankcase)
9 - Oil Filter
10- Oil Cooler
11- Injection Control Pressure Regulator

Injection Pressure Control

The injection control pressure system is a closed loop operating system. The system consists of the (ECM) Electronic Control Module, (ICP) Injection Control Pressure Sensor and the (IPR) Injection Pressure Regulator valve.

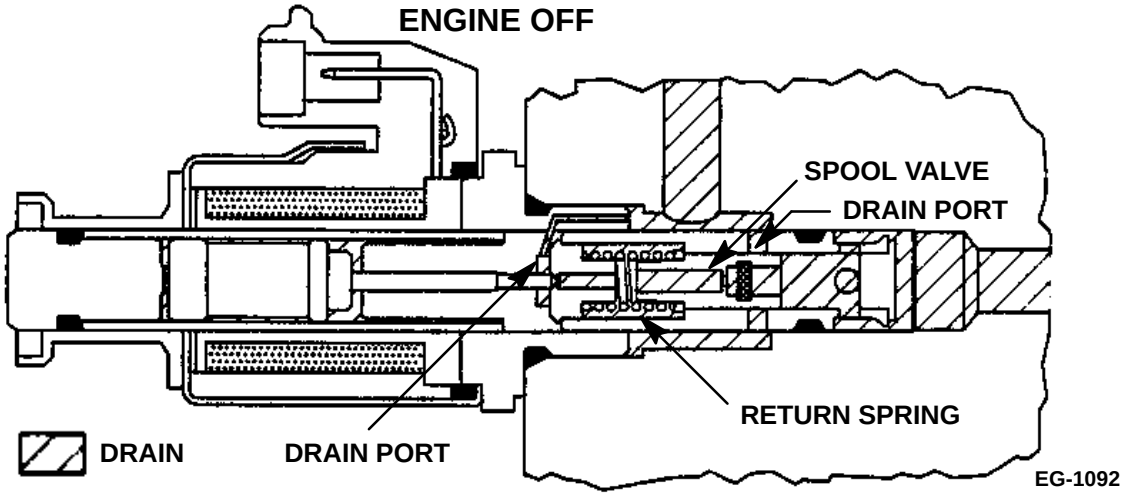
The ECM is programmed with an injection pressure control strategy which determines the correct injection control pressure at each engine operating condition. The ECM receives a 0-5 volt d.c. analog feedback signal from the ICP sensor located in the high pressure oil supply gallery on the left cylinder head that indicates Injection Control Pressure information. The ECM processes this signal and controls Injection Control Pressure by controlling the ground to the IPR regulating valve.



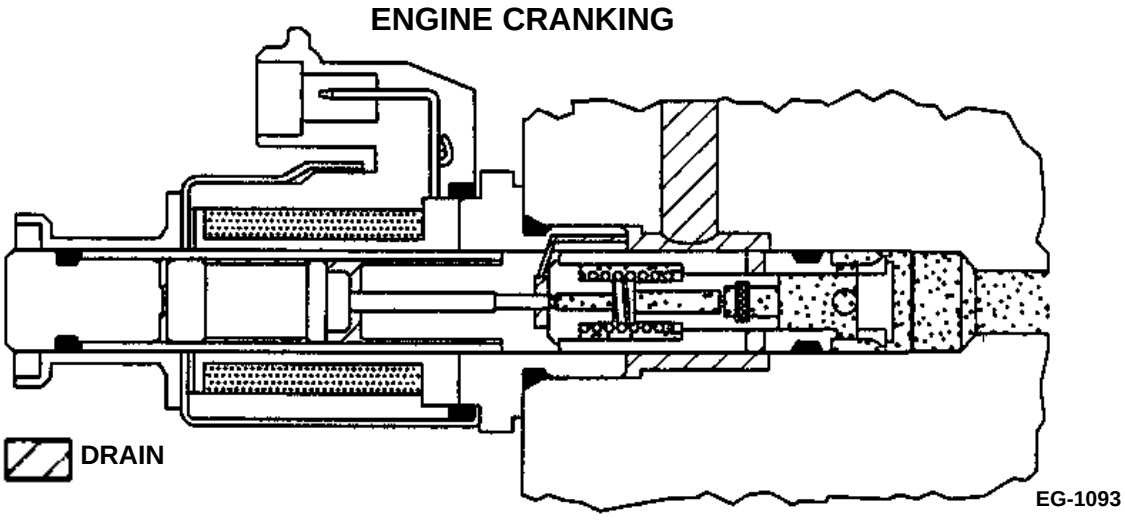
IPR Valve Operation

The Injection Pressure Regulator valve is a pulse width modulated valve operating at 400 Hz. The pulse width is modulated from a duty cycle of 0 to 50% to control ICP pressure from 500 to 3000 psi (3.4 to 20 mPa). The regulator valve is mounted in the high pressure pump and achieves injection control pressure regulation by dumping excess oil through a (shuttle) spool valve into the front cover and back to sump.

The following diagram illustrates the IPR valve in the Engine Off state. The spool valve is held closed (to the right) by the return spring and the drain ports are closed.



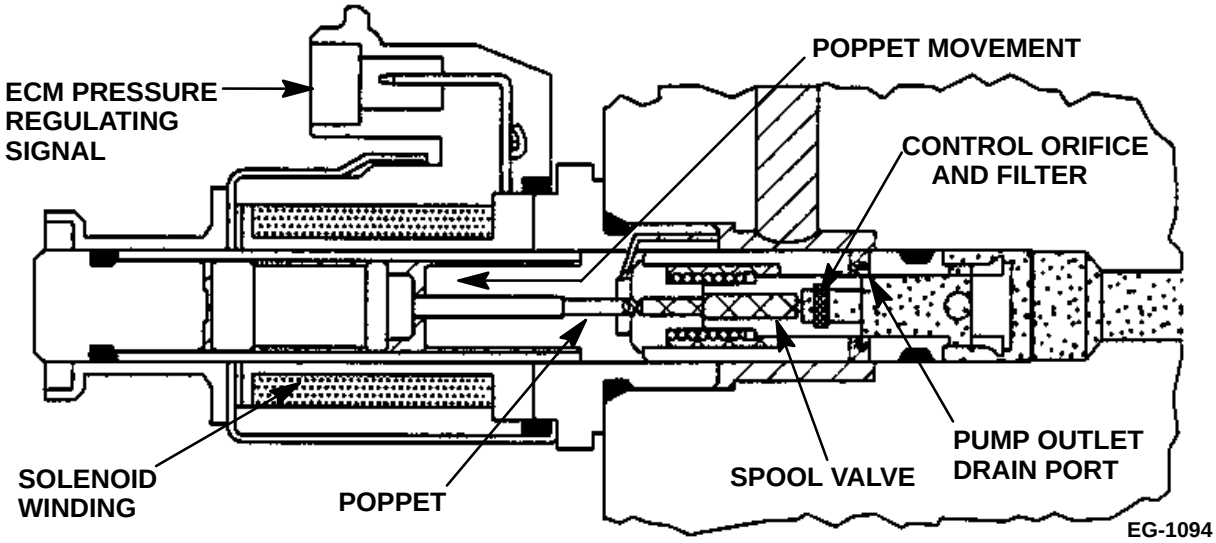
The following diagram illustrates the IPR valve in the Engine Cranking state. The ECM signals the IPR valve to close which directs all the oil to flow into the oil supply galleries to build oil pressure as quickly as possible to start the engine.



PUMP OUTLET PRESSURE

The following diagram illustrates the IPR valve in the Engine Running state. The ECM pressure regulating signal determines the magnetic field strength of the IPR valve solenoid. The magnetic field pulls the poppet to the left as shown. This action allows the pump outlet pressure that is on the spool valve to move the spool valve to the new position of the poppet. Poppet movement allows a small amount of oil to enter the spool chamber through the spool valve control orifice and filter.

ENGINE RUNNING



DRAIN

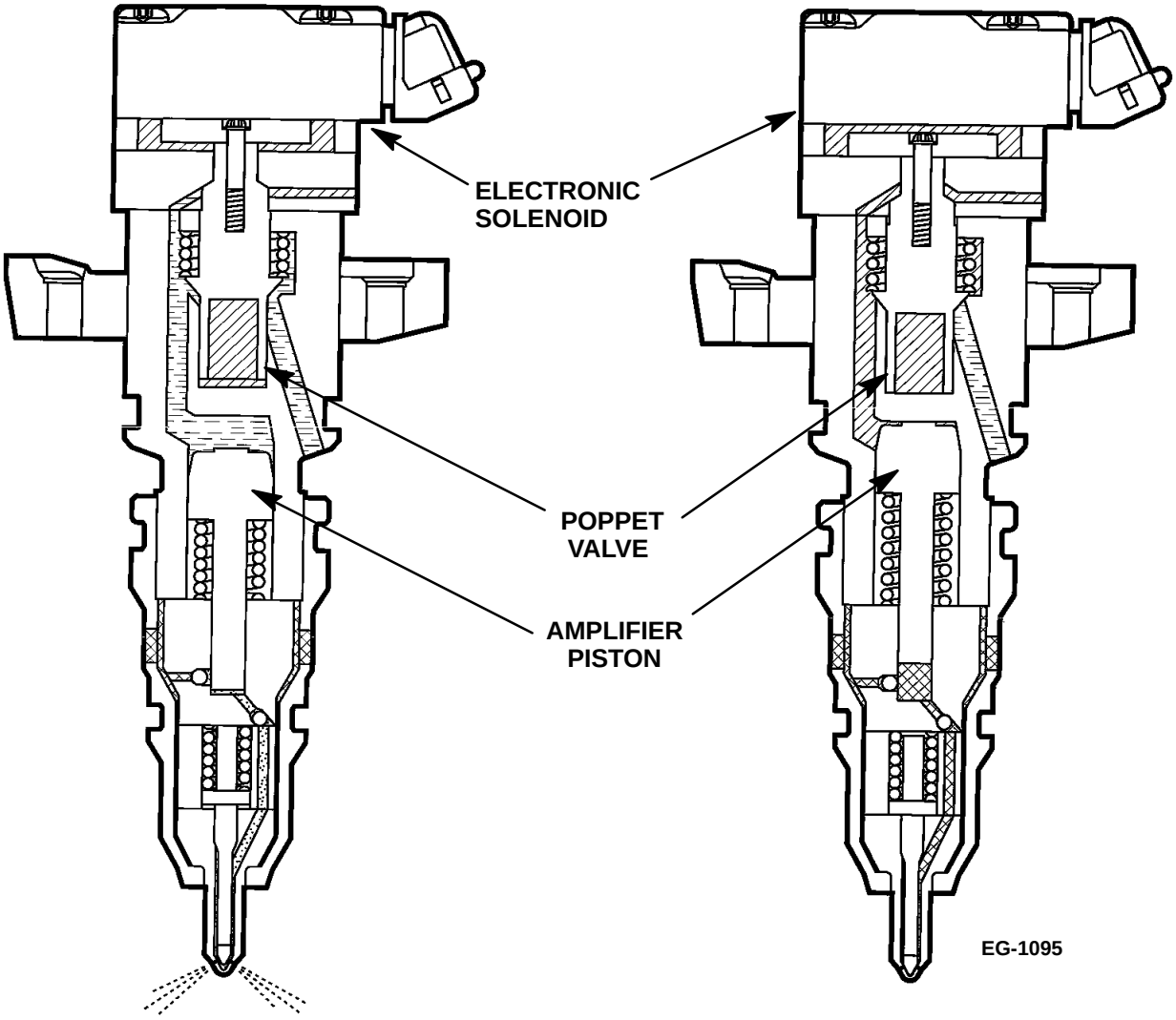
SPOOL CHAMBER PRESSURE

PUMP OUTLET PRESSURE

Injector Operation

Description

When an injector is energized, the poppet valve is opened by an electronic solenoid mounted on the injector. Oil pressure is allowed to flow into the injector and act on the amplifier piston. When injection is ended the pressure on top of the amplifier piston is vented by the poppet valve thru the top portion of the injector and directed by the oil troughs mounted on the injector to a push tube hole for return to the oil sump.



Electronic Control Module

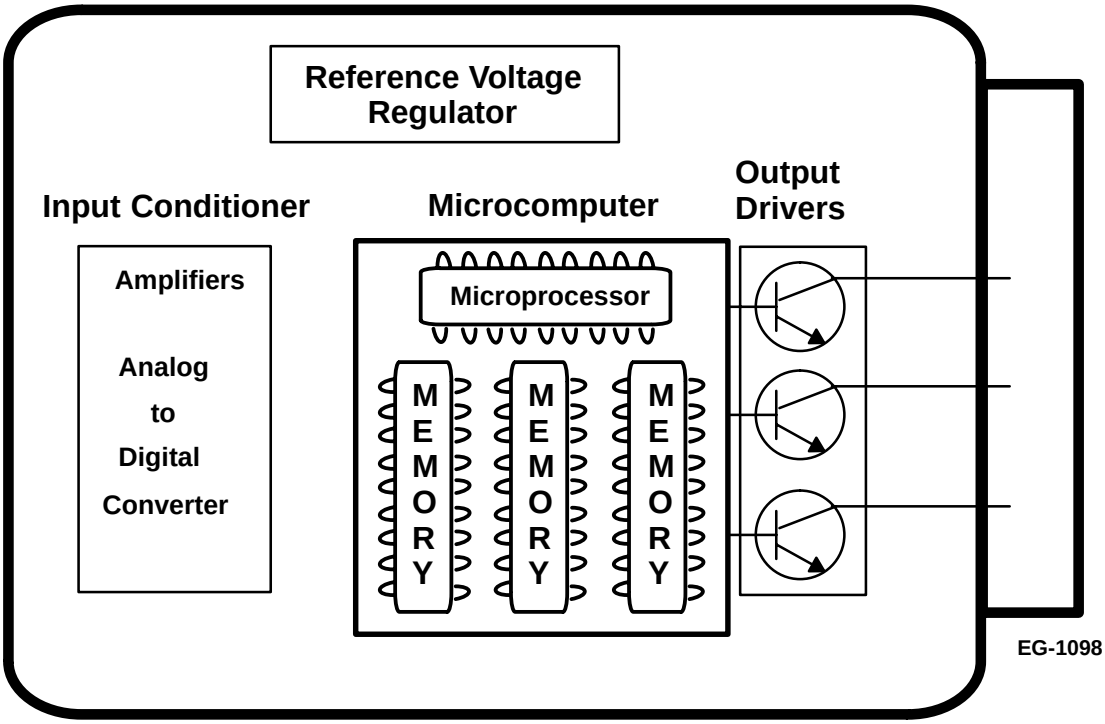
Operation and Function

The Electronic Control Module (ECM) monitors and controls engine performance to ensure maximum performance.

To understand how the ECM functions and how it can monitor input signals and exert control over the actuators it is necessary to view the four primary functions of the ECM.

ECM Functions

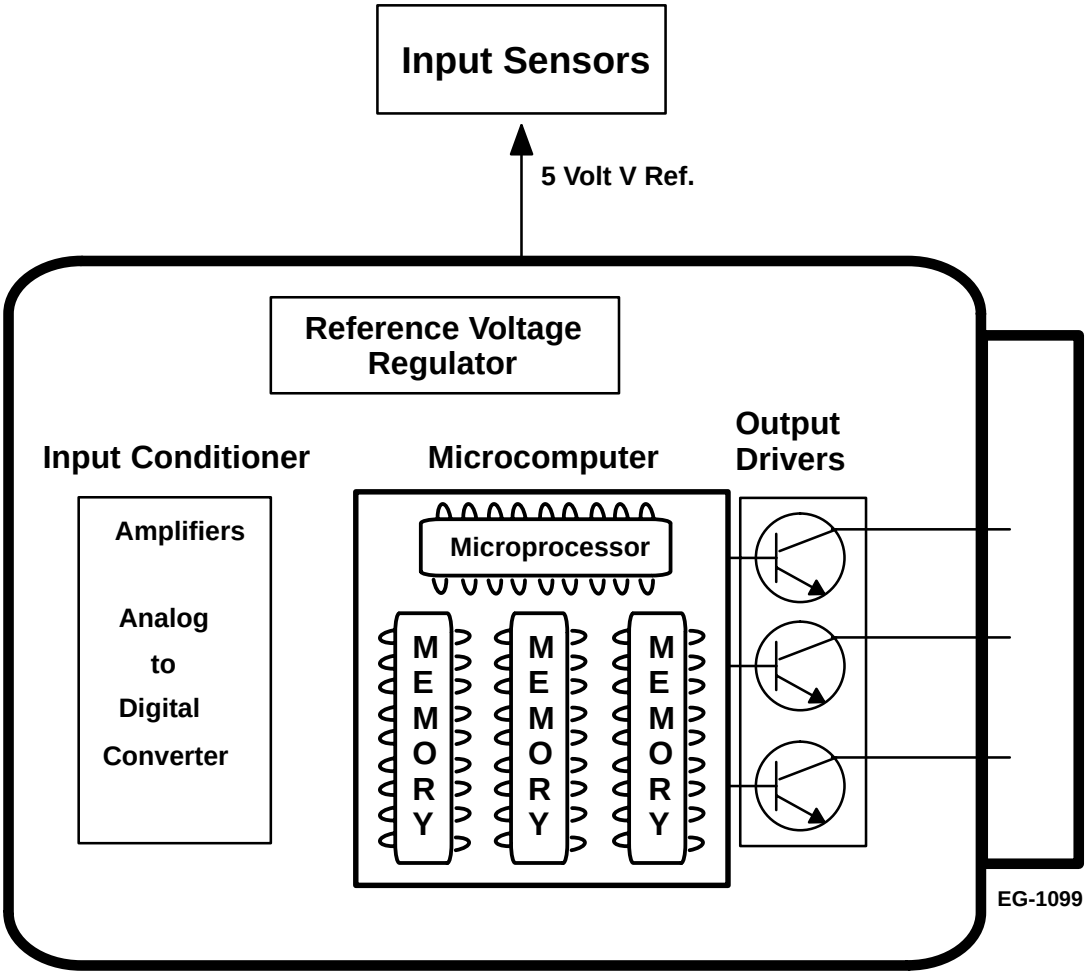
- **Reference Voltage Regulator**
- **Input Conditioners**
  - **AMP**
  - **A/D Converter**
- **Microcomputer**
  - **Processor**
  - **Memory**
- **Actuator Controller Through Output Drivers**
  - **Grounding Transistors**



Voltage Reference

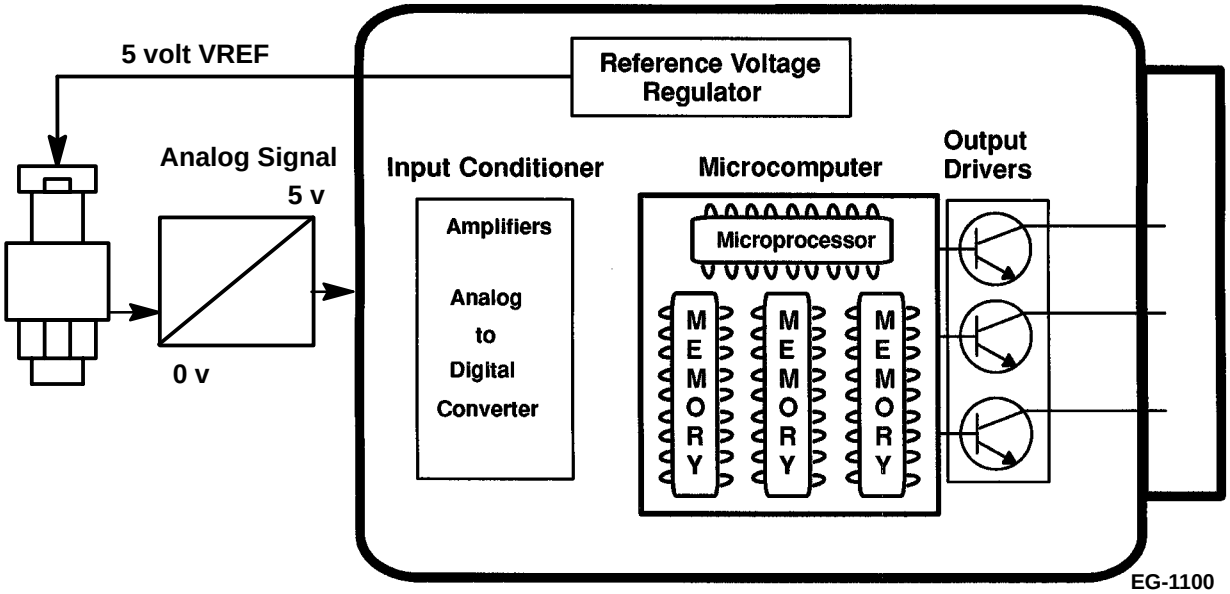
The ECM supplies a 5 volt reference signal to many of the input sensors in the control system. On most circuits the ECM compares the regulated 5 volts sent to the sensors by the modified returned signal and is able to determine temperature, pressure, speed, position and many other variables that are important to engine and vehicle functions. This 5 volt signal is current limited by a current limiting resistor in the event of an external dead short to ground.

For some sensors, like CMP (Camshaft Position), the 5 volts signal is a power source that powers up the circuitry in the sensor.



Signal Conditioner

It conditions the input signals for the internal microprocessor. This enables the microprocessor to interpret the signals. Signal conditioning usually consists of converting analog signals to digital signals, squaring up sine wave signals or amplifying low intensity signals to a level the ECM microprocessor can process.



Microprocessor

The ECM contains an internal microprocessor. The processor stores operating instructions (control strategies) and tables of values (calibration parameters). It compares these stored instructions and values to sensed input values to determine the correct operating strategy for any given engine condition. Calculations in the ECM occur at two different levels or speeds referred to as the foreground and the background calculations. These calculations are performed on a continuous closed loop basis.

The foreground calculations occur at a much faster rate than the background calculations. These are normally the more critical functions to engine operation or they occur at a faster rate. Such as engine speed control. Background calculations are normally things that occur at a slower pace such as engine temperature.

Diagnostic strategies (instructions) are also programmed into the ECM. Some instructions cause inputs or outputs to be monitored on a continuous basis and will flag a code that will be set, other strategies will instruct the ECM to perform certain tests upon operator demand.

The ECM's microprocessor is equipped with three types of memory Random Access Memory (RAM), Read Only Memory (ROM) and Keep Alive Memory (KAM). They allow the processor to store the necessary instructions, calibration tables and input values to control the engine.

ROM

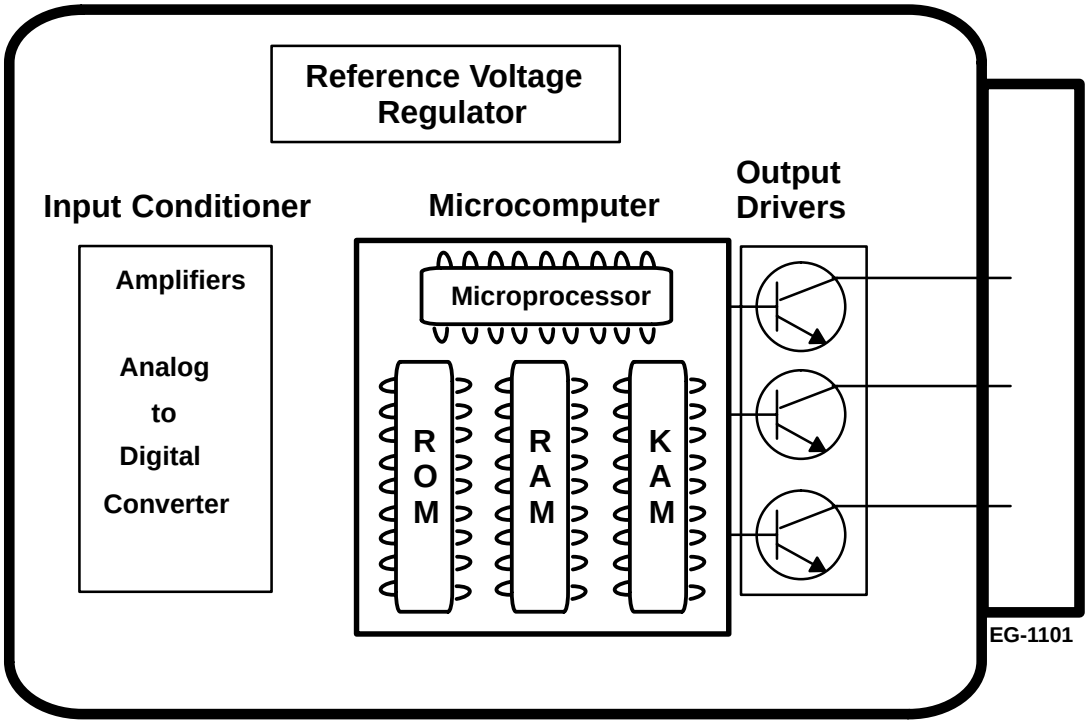
Read Only Memory is the memory where calibration tables and operating strategies are stored. Information in the ROM is permanent. It can not be changed or lost by turning the engine off or disconnecting the batteries.

RAM

Random Access Memory is a temporary storage memory for current events such as current engine temperature or current speed, pedal position etc. It is the memory to which information is temporarily stored so that it can be compared to the information in the ROM. Unlike the Rom memory, the RAM is lost every time the key is turned off or when power is interrupted to the ECM.

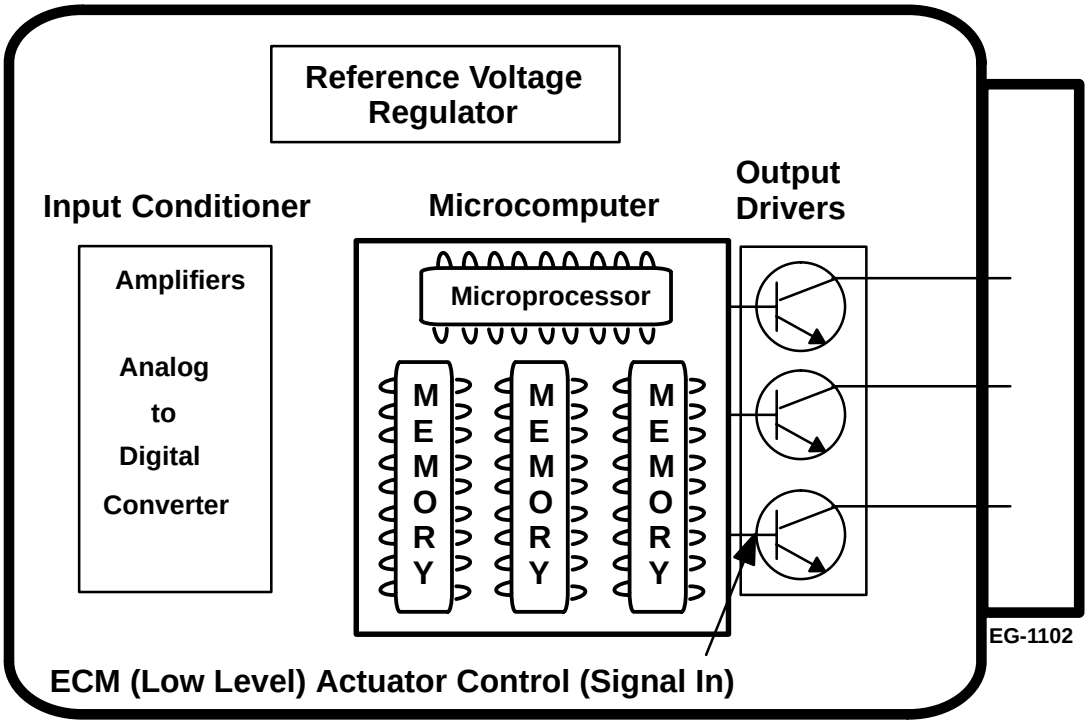
KAM

Keep Alive Memory is a permanent memory. It is used to store diagnostic faults (codes). Adaptive strategies (temporary operating instructions) can also be written to it in event of a system failure or as a compensation for component wear. Uninterrupted power must be supplied from the battery to the ECM on a continuous basis to keep KAM memory alive. All information in KAM is lost if the ECM has a total power loss such as when the batteries are disconnected.



Actuator Control

The ECM controls the actuators by applying a (low level) signal to the base of the transistor output drivers. These drivers, when switched on, will complete the ground circuit of each actuator. The actuators are controlled either thru a duty cycle (% time on/off), or controlled thru a controlled pulse width or simply just switched on or off as determined by the type of actuator being controlled.



Injector Driver Module

Module Functions

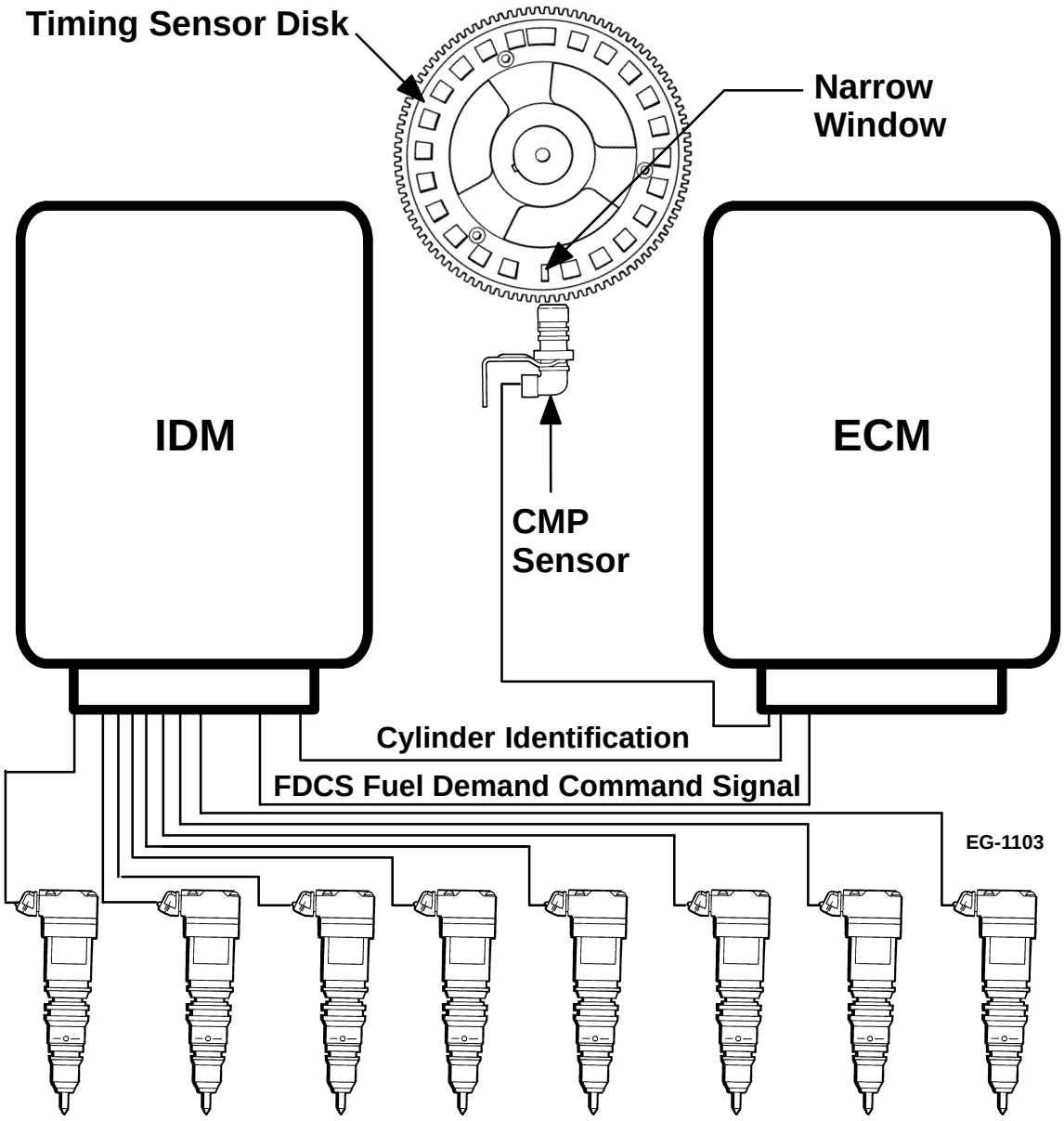
The Injection Driver Module (IDM) is a device that performs four major functions.

ELECTRONIC DISTRIBUTOR FOR THE INJECTORS

Electronic Distributor for the injectors. The Electronic Control Module (ECM) senses the piston position of cylinder #1 from the output signal of the Camshaft Position Sensor (CMP) which is located on the engine front cover. The CMP sensor is a Hall effect sensor which looks for a narrow vane on the timing sensor disk. The disk is precisely mounted and indexed on the camshaft gear in a relationship that identifies the position of #1 piston.

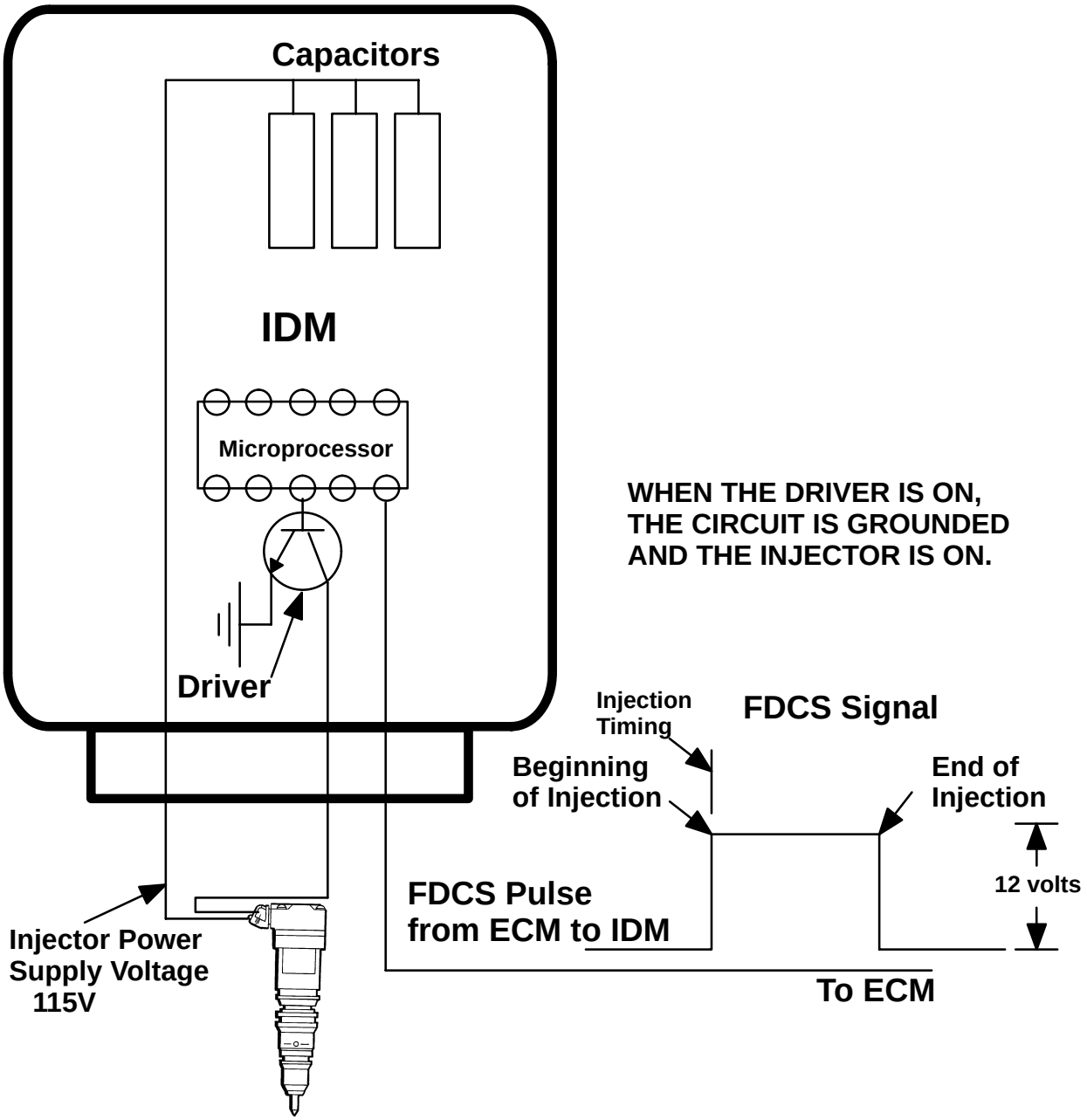
The ECM uses this signal to determine the correct injector firing sequence. The Cylinder Identification (CI) line carries the injector firing sequence information to the IDM.

The IDM receives a Fuel Demand Command Signal (FDCS) signal from the ECM to control injector timing and the quantity of fuel that is delivered by each injector.



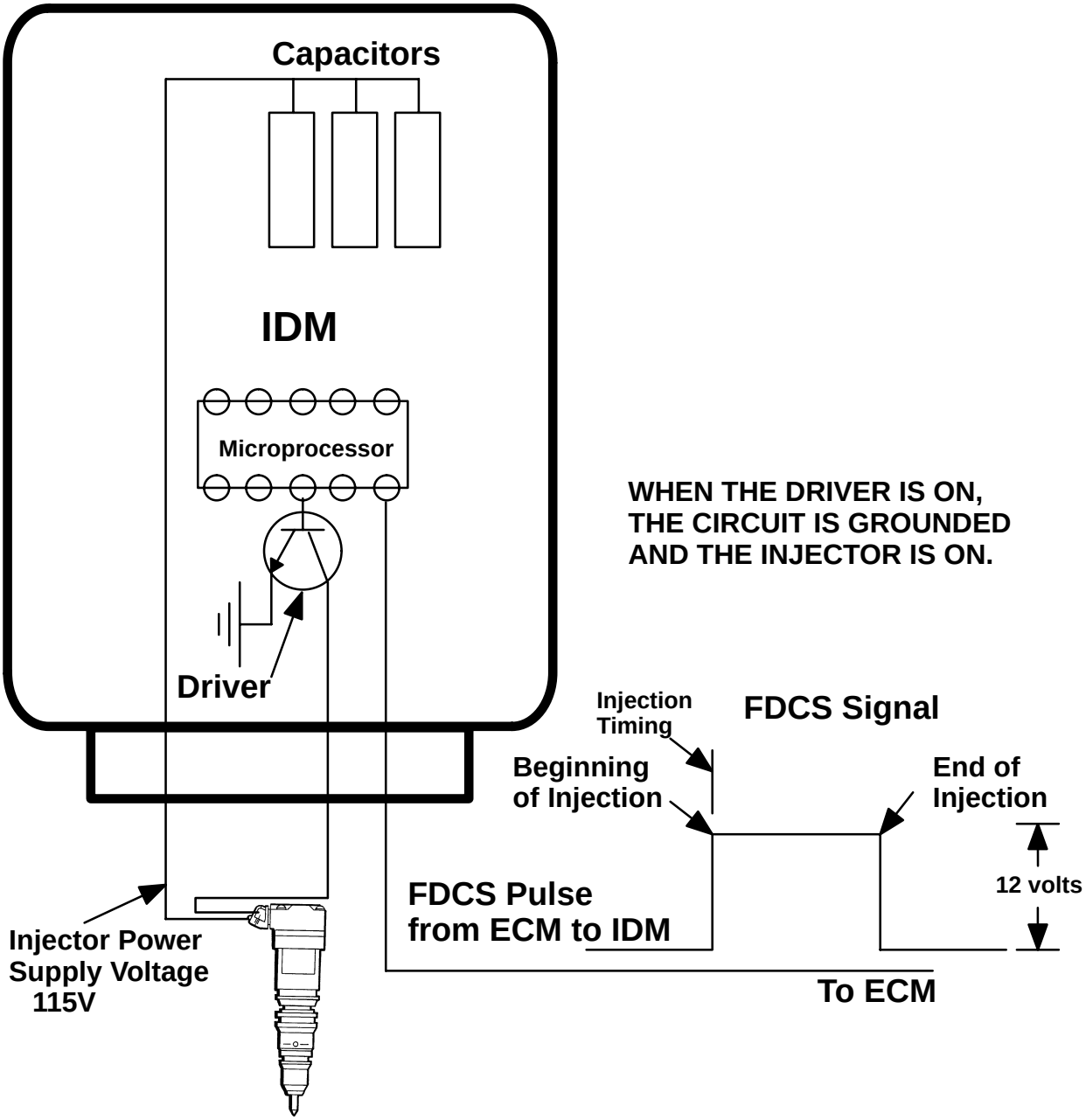
POWER SOURCE FOR THE INJECTORS

Power Source for the injectors. The IDM supplies a constant 115 + volt d.c. supply to all injectors. The 115 volt d.c. supply is created in the IDM by making and breaking a 12 volt source across a coil internal to the IDM, the same principle is used on automotive coils. The resultant 115 + volts created by variations of the magnetic field, is stored in capacitors until used by the injectors.



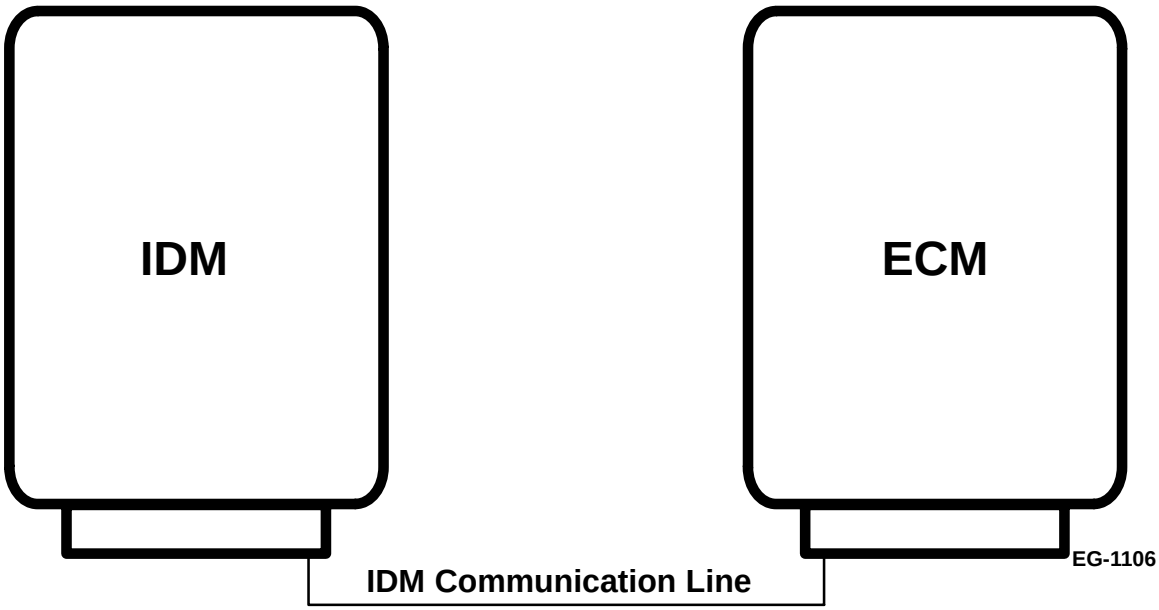
OUTPUT DRIVER FOR THE INJECTORS

Output Driver for the injectors. The IDM controls when the injector is turned on and how long the injector is turned on by closing the circuit to ground by the use of output driver transistors. Each injector has an individual output driver in the IDM. The processor in the IDM selects the correct firing sequence, the ECM through the FDCS signal controls the timing of when the injection starts and the duration of how long the injector is open.



SELF DIAGNOSTICS

Performs diagnostics for itself and the injectors. The IDM is capable of identifying if an injector is drawing too much current or too little current and sends a fault code to the ECM that can be accessed by the technician. This code can be used to identify potential problems in either the wiring harness or injector. The IDM also performs self diagnostic checks that can set a code to indicate that the IDM has failed and needs to be replaced.



Sensor Operation

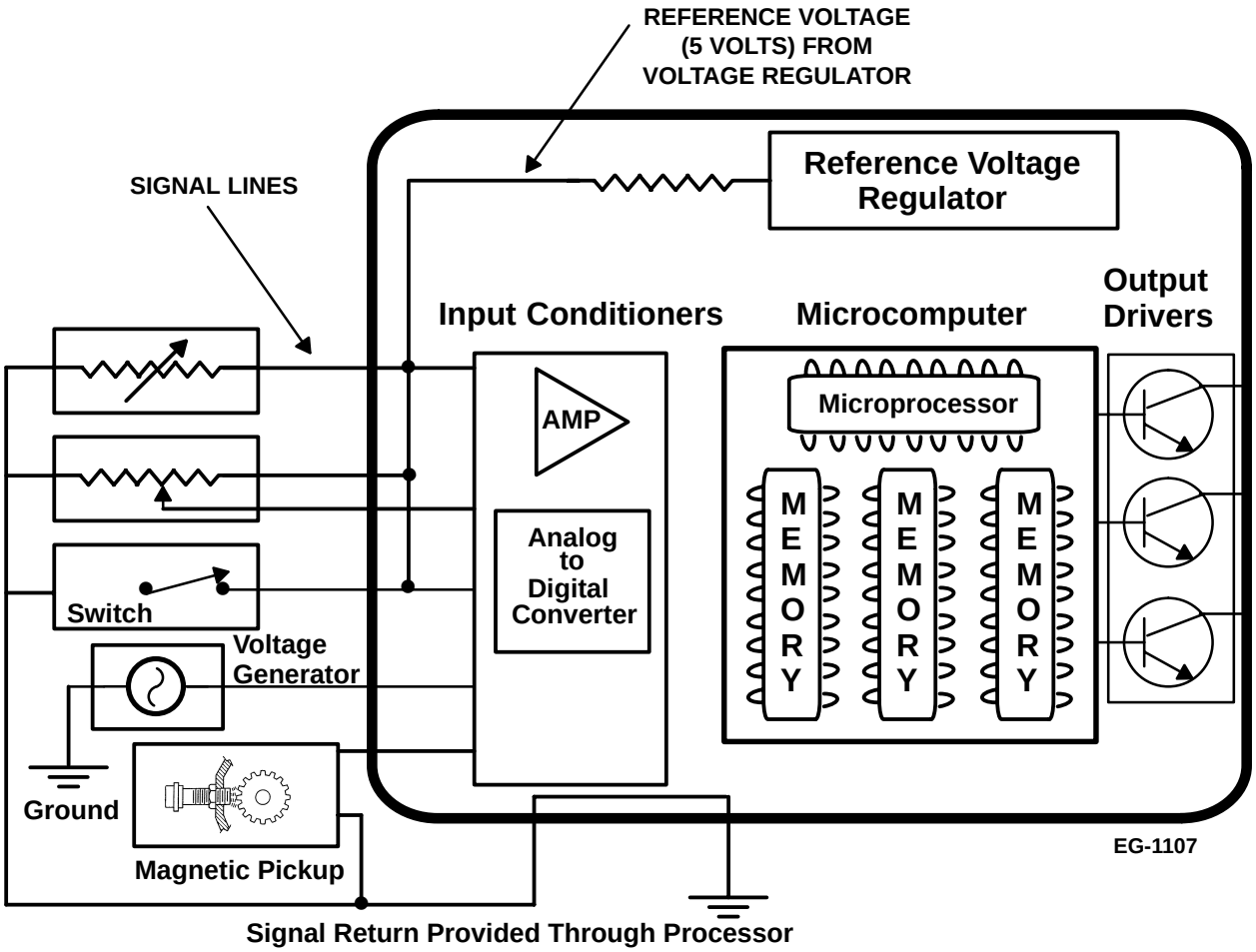
Input Signals

Engine and vehicle sensors transmit input signals to the Electronic Control Module (ECM) by either:

- Controlling a reference voltage to produce an analog or digital signal.
- Generating a signal voltage.
- Switching a 12 volt signal.

Reference Voltage Sensors

Reference voltage sensors are supplied with a constant 5 volts regulated supplied by the ECM. A voltage regulator supplies the reference voltage (Vref) to these sensors. This voltage is changed by the sensor and the signal is relayed back to the ECM. The ECM, by comparing the Vref to the returned signal can check it's internal programmed tables to determine the value of the variable being measured.



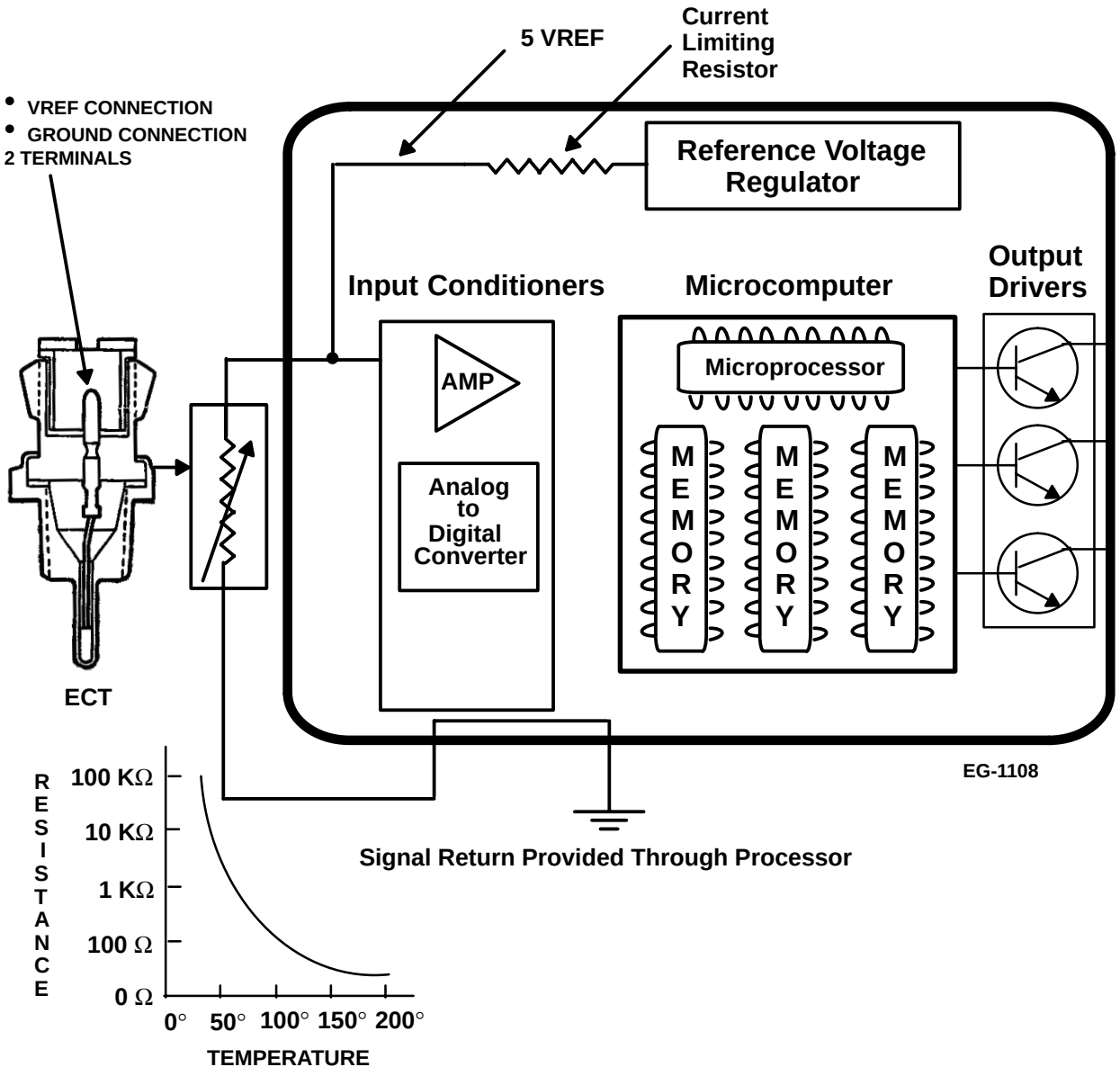
Thermistor

A thermistor is a type of sensor which changes it's electrical resistance with temperature. The electrical resistance of the thermistor decreases as temperature increases and increases as temperature decreases. The thermistor in conjunction with a current limiting resistor in the ECM forms a voltage divider network that provides a voltage signal that indicates temperature.

The top half of the voltage divider is the current limiting resistor internal to the ECM. A thermistor sensor has two electrical connections, signal return and ground. The output of a thermistor sensor is not linear.

Examples:

EOT Engine Oil Temperature
ECT Engine Coolant Temperature Sensor
IAT Intake Temperature Sensor



The chart indicates resistance of a thermistor decreases as temperature increases. Output of thermistor is not linear.

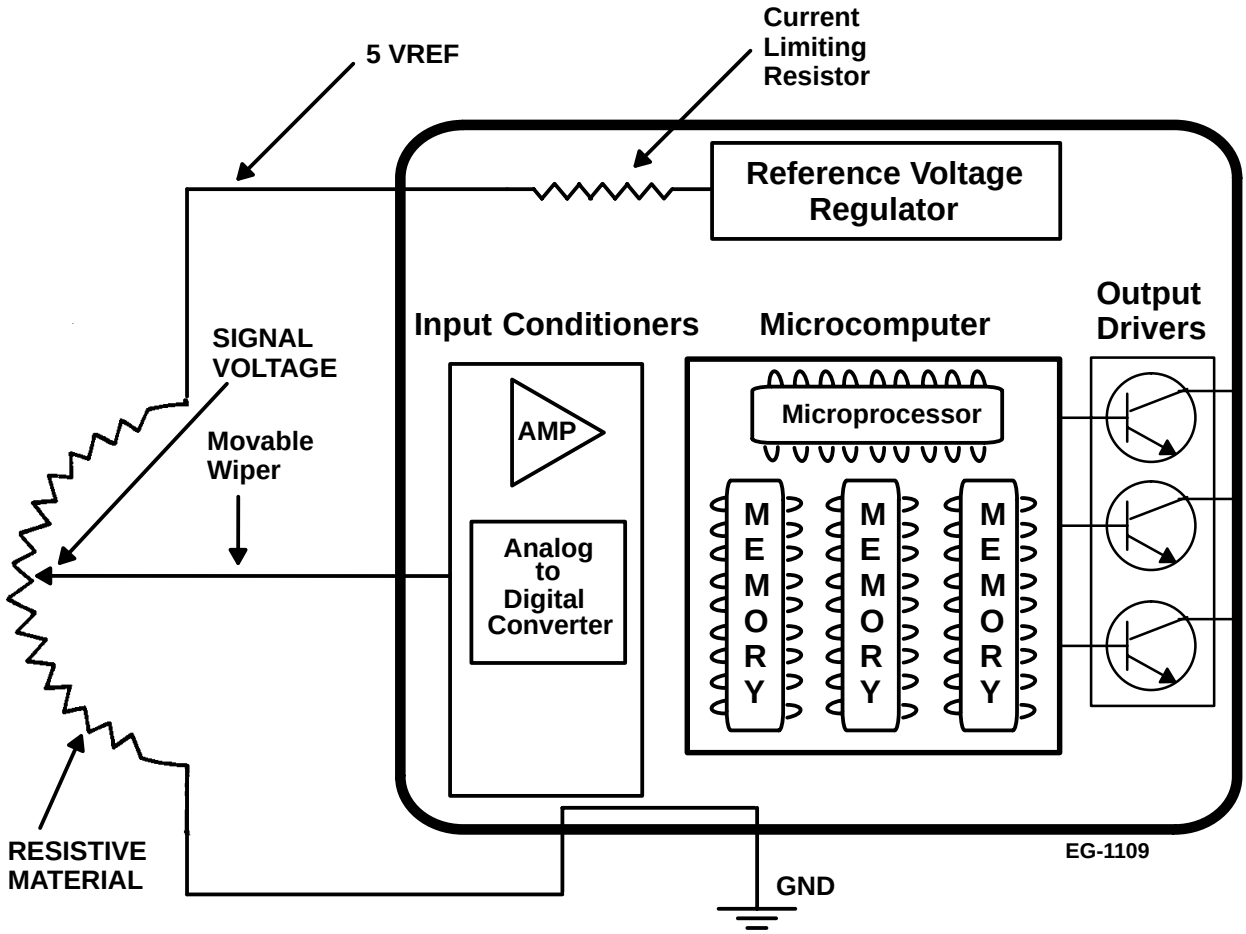
Potentiometer

A potentiometer is a variable voltage divider used to sense the position of a mechanical component. A reference voltage is applied to one end of the potentiometer. Mechanical motion connected to the wiper causes it to move along the resistance material in a rotary fashion.

The voltage on the wiper changes at each point along the resistive material. This voltage is proportional to the amount of mechanical movement.

Example:

APS Accelerator Position Sensor



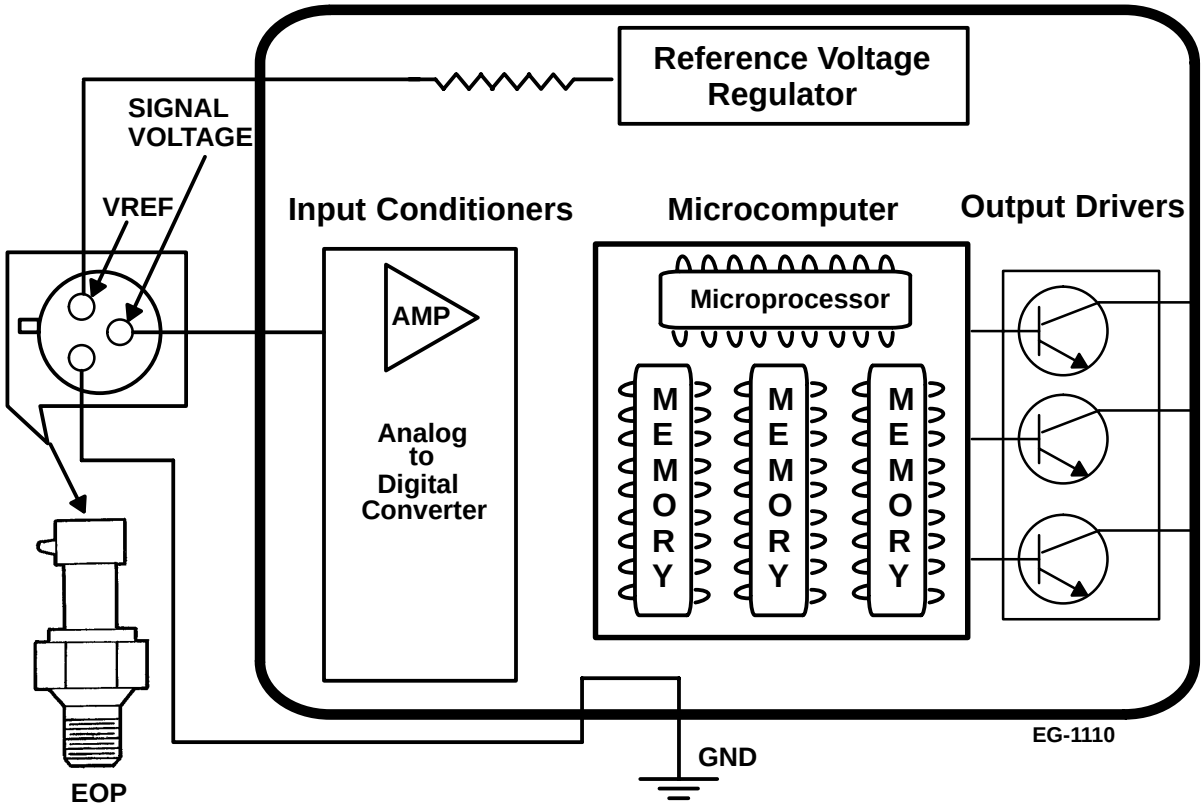
Variable Capacitance Sensor

Variable capacitance sensors are used to measure pressure. The pressure which is to be measured is applied to a ceramic material. The pressure forces the ceramic to move closer to a thin metal disk. This action causes the capacitance of the sensor to change which creates a frequency that corresponds to a pressure.

The internal circuitry of the sensor converts that frequency into a linear analog voltage that indicates pressure. The thicker the ceramic disk the more pressure that sensor can measure. A variable capacitance sensor has three connections: Vref, signal and ground.

Examples:

EOP Engine Oil Pressure Sensor
ICP Injection Control Pressure Sensor



Hall Effect Sensor

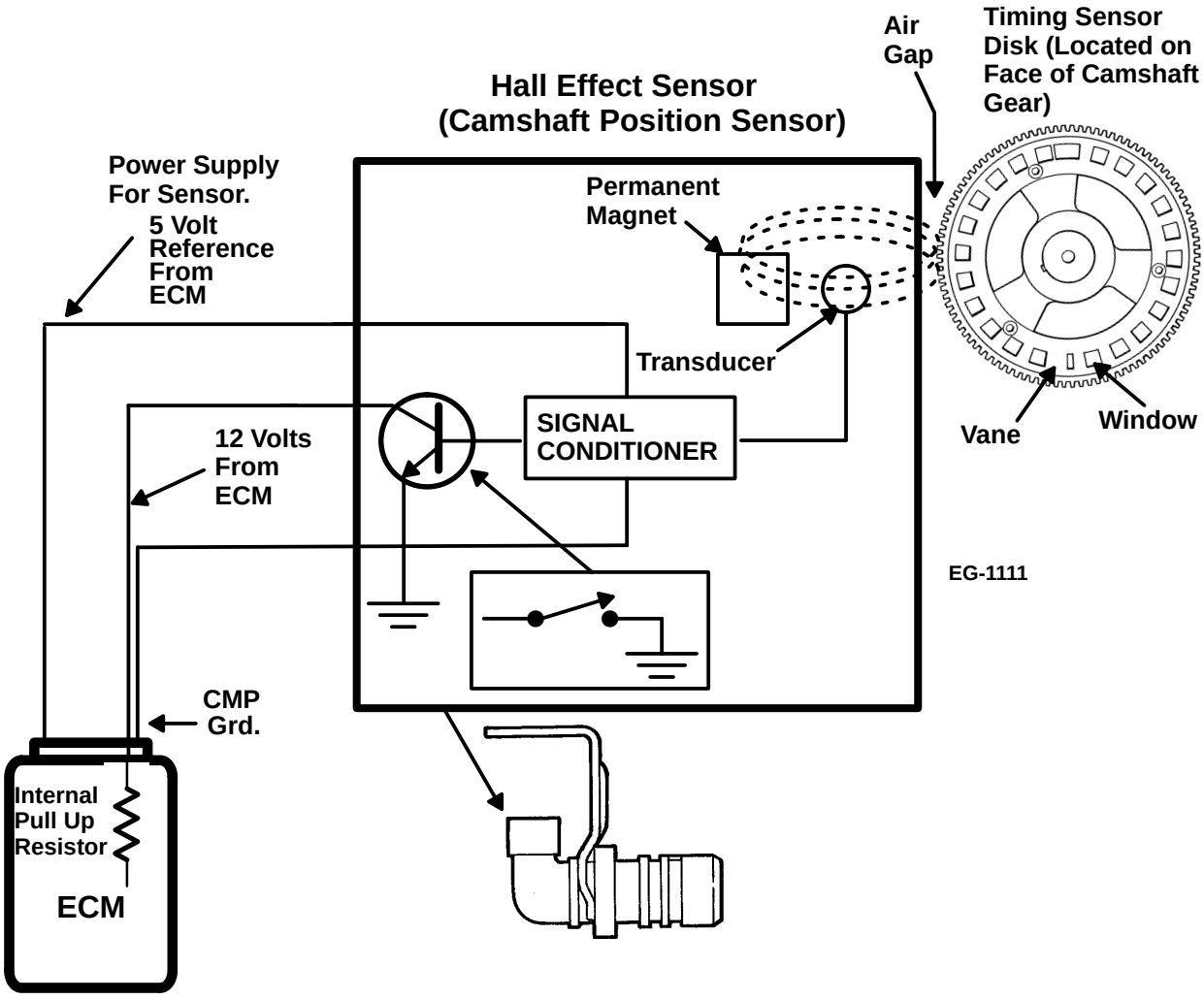
The Hall Effect sensor is an electronic device which generates a voltage signal controlled by the presence, absence or strength of a magnetic field.

The Camshaft Position sensor is an example of a Hall Effect device. It contains a transducer, permanent magnet, signal conditioner and a switching transistor. The sensor's permanent magnet applies a magnetic field around the transducer as shown. The sensor's transducer senses the strength of the magnetic field which is controlled by the vanes and windows (located on the rotating timing sensor disk) as they pass the sensor.

A voltage signal is generated by the Hall Effect device each time a window passes the device. The signal is filtered and conditioned by the signal conditioner. The conditioned signal is applied to the switching transistor's base which causes the transistor to switch on and ground the 12 volt line from the ECM. The ECM no longer senses the 12 volt reference signal.

Each time a vane passes the Hall Effect device no signal is generated. This action causes the transistor to shut off and causes the ECM to see its 12 volt reference signal.

This switching action allows the ECM to determine crankshaft position and engine speed which is required by the ECM to control engine operating parameters such as injector timing and injection duration.



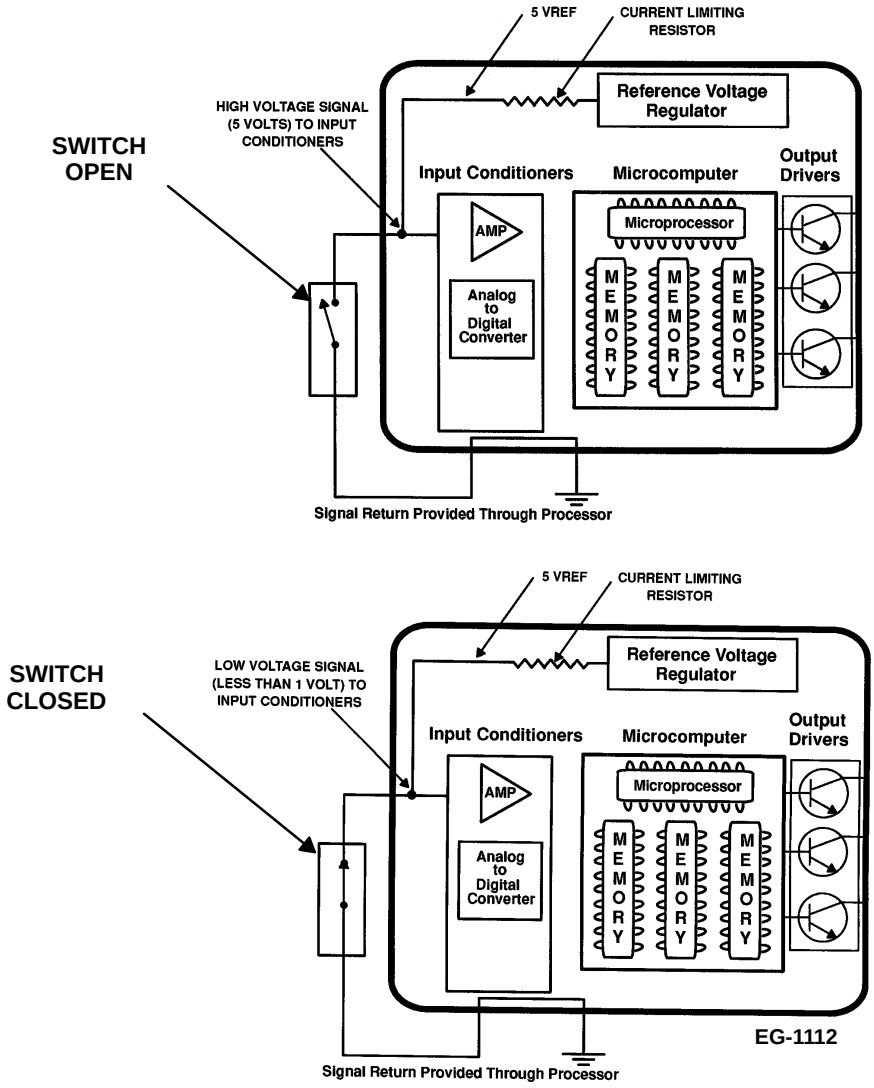
Switch Sensors

Switch sensors are used to indicate position or pressures. The signal of a switch sensor is a digital signal created by either opening or closing a switch. The on or off signal can indicate position as in the case of an idle validation switch or pressure as in the case of a low oil pressure switch. A switch sensor can be either a voltage input type switch or a grounding type switch.

A voltage input style switch will supply the ECM with a voltage when closed. A grounding type switch is wired in series with a current limiting resistor in the ECM and will cause a zero voltage signal when closed (grounding the circuit). A switch sensor normally has two connectors signal return (Grd) and the signal. A switch sensor is considered a low speed digital input.

Example:

IVS Idle Validation Switch



Standard Features

Electronic Governor Control

The D7.3L D-Tronic engine is electronically governed over all operating ranges.

Glow Plug Assisted Start

This feature increases engine startability in cold weather. The glow plugs are controlled by the Electronic Control Module which monitors engine temperature. “A WAIT TO START“ lamp is included to inform the operator when the engine is ready for cranking.

ATA Data Link

The engine is equipped with an American Trucking Association (ATA) data link connector that allows communication between the electronic engine control system and the Pro-Link® 9000 Electronic Service Tool (EST).

The data link provides communication capabilities for:

- Engine parameter data transmission.
- Diagnostics and troubleshooting.
- Production line programming of vehicle features.

Service Diagnostics

The electronic service tool provides means for obtaining diagnostic information using the ATA data link. The recommended electronic service tool is the Pro-Link® 9000 with an International cartridge. Sensor, actuator, electronic component and engine system faults can be detected by the ECM and be diagnosed by the EST.

The engine control system also provides service diagnostic information via flash codes emitted using the engine warning lamp. The service literature is indexed according to the flash codes.

Engine Over-Temperature Protection

This system reduces fuel delivery when the engine coolant temperature is above the cooling system design target value. Fueling is reduced proportionally to the extent the design limit is exceeded. The reduction is calibrated to a maximum of 20% before standard engine warning and/or optional warning/shutdown systems engage. If this feature is activated, a fault code is stored in the Electronic Control Module’s memory to explain low power complaints.

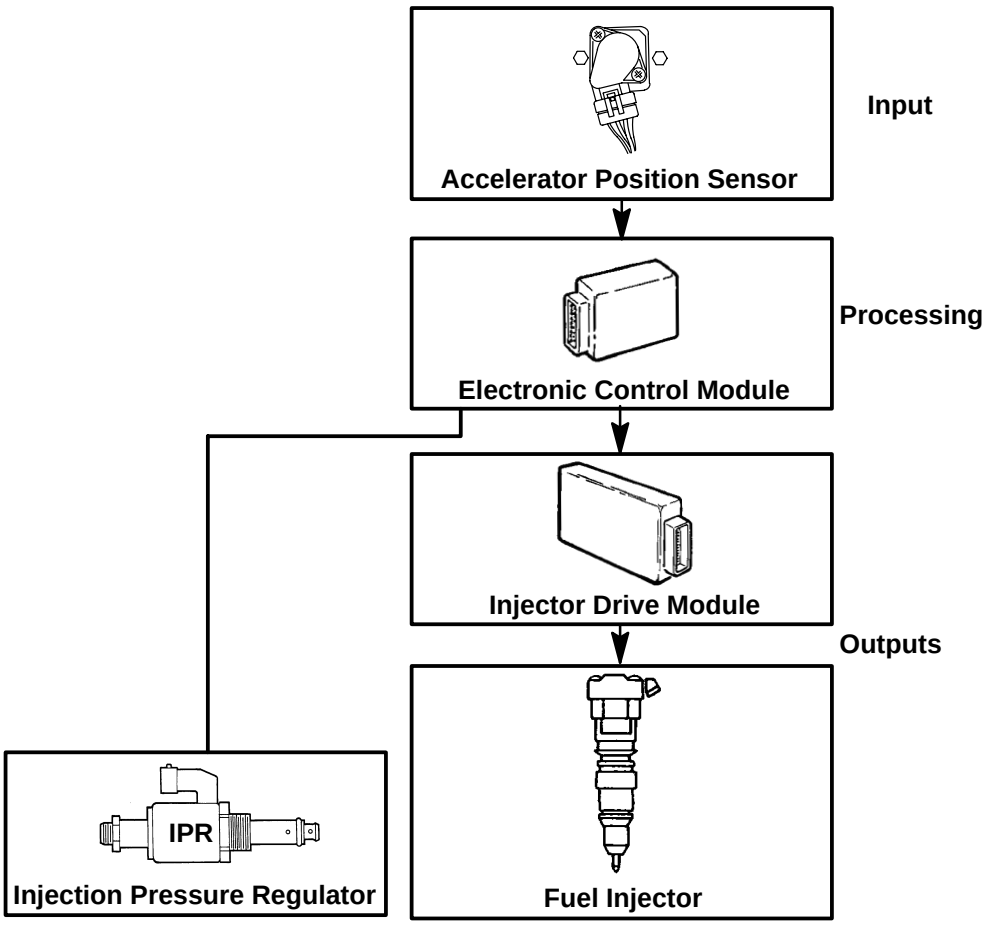


Event Logging System

This system records if the engine was operated beyond maximum rpm, over heated (coolant temperature), low on coolant and/or experienced low oil pressure. This information is stored in the ECM memory and may be accessed through the use of the EST.

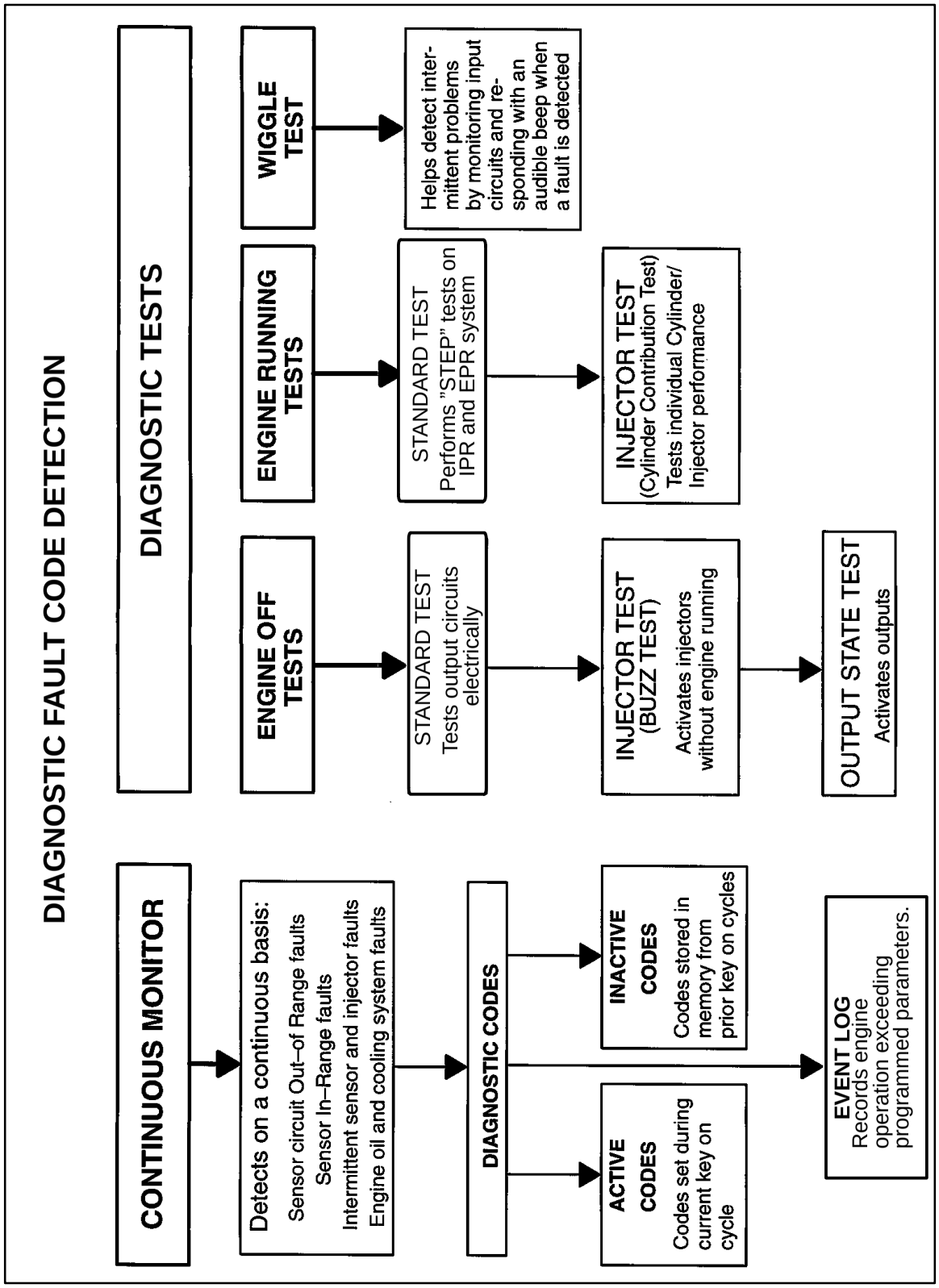
Electronic Throttle Position

An accelerator position sensor provides the ECM with a signal representing the driver's demand for power.



Diagnostic Software Self Test Operation

Test Chart


DIAGNOSTIC FAULT CODE DETECTION
CONTINUOUS MONITOR
Detects on a continuous basis:
Sensor circuit Out–of Range faults
Sensor In–Range faults
Intermittent sensor and injector faults
Engine oil and cooling system faults
DIAGNOSTIC CODES
ACTIVE CODES
Codes set during current key on cycle
INACTIVE CODES
Codes stored in memory from prior key on cycles
EVENT LOG
Records engine operation exceeding programmed parameters.
DIAGNOSTIC TESTS
ENGINE OFF TESTS
STANDARD TEST
Tests output circuits electrically
INJECTOR TEST (BUZZ TEST)
Activates injectors without engine running
OUTPUT STATE TEST
Activates outputs
ENGINE RUNNING TESTS
STANDARD TEST
Performs "STEP" tests on IPR and EPR system
INJECTOR TEST
(Cylinder Contribution Test)
Tests individual Cylinder/ Injector performance
WIGGLE TEST
Helps detect intermittent problems by monitoring input circuits and responding with an audible beep when a fault is detected

Continuous Monitor

Diagnostics are performed by the Electronic Control Module (ECM) continuously to detect out of range, rationality and system faults.

During the time that the key is “ON”, if an input signal is “Out of Range” meaning the signal is either greater or lesser than what the signal range should be during normal operation, the ECM will record a “Fault”. It will also monitor the operation of systems and will determine if the system is working within a normal range. If the ECM detects that a system falls outside a predetermined range, it will record and flag a fault.

During normal engine operation, the ECM automatically performs several tests to detect faults. When it has detected a fault, the ECM often invokes a fault management strategy to allow continued, though sometimes degraded, engine operation.

A “Fault” is an indication of a malfunction measured or monitored electronically. Sometimes “Faults” are referred to as “Codes.”

“Codes” are three digit numbers assigned to Faults to indicate the source of the malfunction. Most Codes will indicate the source and the “Mode” of failure. The “Failure Mode” will indicate the signal reading, i.e.; “Out of Range High”, “Out of Range Low” or in Range fault.

During operation with the engine running, the Vessel Personality Module (VPM) memory will record “EVENT ENGINE HOURS”. This is the monitoring of engine operation exceeding programmed parameters. The standard Engine Event is Overspeed of the engine, referred to as Over RPM and excess coolant temperature. To retrieve information on Engine Events, it will be necessary to access them with the Electronic Service Tool.

If the engine is equipped with the optional engine warning/shutdown system, low oil pressure, will also be monitored and recorded as “EVENT ENGINE HOURS”.

Operator “On Demand” Tests (Engine Off)

“Engine Off Tests” are “Standard Tests” performed by the ECM. These tests are commanded by the operator using the Electronic Service Tool (EST) or using the Self Test Input (STI) push-button switch. Since Injector Driver Module (IDM) faults are not stored in the ECM, it will be necessary to perform a self test to transmit faults from the IDM to the ECM.

To use the EST, access the Engine menu and select Diagnostic Tests. Then select Engine Off Tests. Depressing the Enter key will initiate the test.

To use the STI diagnostic push-button switch, depress the switch and hold in, while turning the ignition switch to the “ON” position. Release the STI button after the key is in the “ON” position. **Do not start the engine.**

When the operator signals the test to begin, the ECM will perform internal tests of its processing components and internal memory.

It will automatically proceed to Output Circuit Check (OCC). This will operate the ECM output circuits. It will measure each individual circuit’s response. The following circuits are checked by the ECM during the test:

- Cylinder identification
- Glow Plug Control (relay)
- Injector Driver Module (relay)
- Glow Plug Light
- Fuel Demand Command Signal
- Injection Pressure Regulator

The ECM will monitor the outputs and test the operation of the output signals and actuators. If a circuit fails the test, a fault code will be logged.

When the test is complete, the EST will display any faults that were found during the test. If the STI diagnostic switch was used, the faults will be transmitted as “Flash Codes,” using the Oil Warning and Engine Warning lights.

The fault codes are read by counting the number of light flashes. The following sequence occurs:

1. The **“OIL/WATER”** light will flash one time. This indicates the beginning of Active Fault Codes.
2. The **“WARN ENGINE”** light will flash repeatedly signaling the active fault codes. All codes are three digits. The number of flashes should be counted in sequence.

3. At the end of each digit of the code there will be a short pause. Three flashes and a pause indicates the number 3. The code 232 will be sent as two flashes, (a pause), three flashes, (a pause), and two flashes.

If there is more than one code being sent, the **"OIL/WATER"** light will flash once indicating the beginning of another active fault code. The code 111 indicates "NO FAULTS".

If no further Active Fault Codes exist, the **"OIL/WATER"** light will flash twice, indicating the beginning of "INACTIVE CODES". The **"WARN ENGINE"** light will then flash the "INACTIVE CODE(s)" present. If several "INACTIVE CODES" are present, the **"OIL/WATER"** light will flash once between each of the fault codes.

When all of the stored fault codes have been sent, the **"OIL/WATER"** light will flash three times indicating "END OF MESSAGE".

If it is necessary to repeat transmission of fault codes, press the STI button and all stored codes will be retransmitted as described previously.

INJECTOR BUZZ TEST

The purpose of the Engine Off Injector "BUZZ" Test is to diagnose electrical problems with the fuel delivery components. This test can only be accessed with the EST and only after an "Engine Off Test" or Self Test has been performed.

NOTE:*Before running this test, fault codes should be accessed, noted and erased. This will allow the faults found in this test to be displayed as "ACTIVE CODES".*

During the test, the ECM will signal the IDM to activate the injectors in numerical order 1 thru 8. The IDM will monitor each injector's electrical circuit operation. The IDM will send feedback signals to the ECM which indicate the status of injector performance and electrical circuit operation. If an electronic component in the fuel system fails the parameters of the test, an inactive fault code will be logged and transmitted to the EST at the end of the test.

NOTE:*The technician can monitor injector operation by listening to the sound each injector produces as it is activated by the idm, however, in a hard start/no start condition where the oil may be very cold/thick, injectors may not be audible.*

If the faults were not erased before this test, the faults found during this test will be displayed as "INACTIVE CODES".

To read these fault codes, access the "Diagnostic Codes" menu and read both Active and Inactive codes.

OUTPUT STATE TEST

The purpose of the Output State Test is to diagnose the operation of the output signals and actuators. This test can only be performed by using the Electronic Service Tool.

To run this test, select the Output State Test from the EST Engine Off Test menu. The test consists of two modes of operation:

1. Toggling outputs from high to low.
2. Toggling outputs from low to high.

When in the **"OUTPUTS ARE LOW"** mode the ECM will pull down the output voltage to their low state. This will actuate the output components that are controlled by the ECM grounding the circuits. During this test **"OUTPUTS ARE LOW"** will be displayed on the screen.

When in the **"OUTPUTS ARE HIGH"** mode the ECM will pull up the output voltage to their high state. This will actuate the output components that are controlled by the ECM energizing the control circuits. During this test **"OUTPUTS ARE HIGH"** will be displayed on the screen.

During this test, the output of the circuit in question can be monitored with a DVOM. The DVOM will measure a "High or Low" voltage state condition as the outputs are toggled. The actual voltage will vary with the circuit tested.

NOTE:*The EST will only display "outputs are high" or "outputs are low". It will not display any voltages etc. A DVOM is required to monitor the suspected problem circuit or actuator.*

NOTE:*Faults will not be set during this test.*

This following actuators and signals are toggled high and low during the test:

- Injector Driver Module Enable Relay
- Cylinder Identification
- Fuel Demand Command Signal (FDCS)
- Injection Pressure Regulator
- Engine Data Link (EDL) Relay
- Oil Warning Light
- Warm Engine Light
- Glow Plug Lamp
- Glow Plug Relay

Operator "On Demand" Tests (Engine Running):

STANDARD TEST

The Self Test (Engine Running) checks the operation of the Injection Pressure Regulator (IPR)

During the test, the ECM commands the IPR actuator through a preprogrammed testing sequence to determine if the actuators are performing as expected. The ECM monitors the feedback signal values from the injection control pressure sensor and compares that value to the expected value. At the end of the test, the ECM will return the engine to the normal operating mode and transmit any fault codes which may have been set during the test.

This test can only be performed by using the Electronic Service Tool.

Procedure

NOTE:*Engine coolant temperature must be 160°f , battery voltage must be higher than 12.5 volts. If Active Fault Codes are present, they must be repaired and cleared prior to running this test.*

1. Select **"**Engine Running Test" from the **"Diagnostic Test"** menu in the EST.
2. Press **"ENTER"** to begin test. The ECM will begin to raise the engine idle speed to a predetermined value. It will then command the IPR valve to set the injection control pressure to rated speed pressure. If the performance of the IPR is acceptable,the ECM will control the IPR valve to reduce the pressure in steps while continuing to monitor the performance of the injection control pressure system.

When testing is completed, normal engine operation is restored and fault codes will be transmitted as described previously.

INJECTOR TEST "CYLINDER CONTRIBUTION"

The Injector Test is designed to detect problems with injection and combustion events. During the test the ECM will control fuel delivery and determine each cylinder's power contribution. If a cylinder is not performing satisfactorily, a fault code will be set.

This test can only be performed by using the Electronic Service Tool.

Procedure

NOTE:*The engine running self test must be performed first in order to gain access to the injector (engine running) test in the EST.*

1. Select Injector Test from the Engine Running Test menu.
2. The ECM will increase the normal amount of fuel delivery (overfuel) to the injector/cylinder being tested and monitor the reduction of fuel required to operate the remaining injectors to maintain engine speed. If there is no reduction in fuel delivery to the other cylinders the ECM will set a fault code identifying the non-contributing cylinder.

When testing is completed, normal engine operation is restored and fault codes will be transmitted.

Operator “On Demand” Tests:

WIGGLE TEST

The purpose of the Wiggle Test is to troubleshoot intermittent connections at sensors and actuators. It may be performed with the engine off or running. The Electronic Service Tool is used to monitor the following circuits during the Wiggle Test:

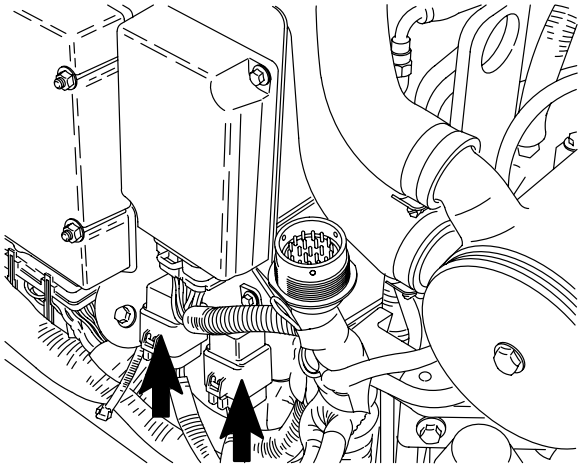
- Accelerator Position Sensor (APS)
- Intake Air Temperature Sensor (IAT)
- Camshaft Position Sensor (CMP)
- Data Communication Link
- Engine Coolant Temperature
- Engine Oil Pressure
- Injection Control Pressure
- Manifold Absolute Pressure
- Engine Oil Temperature

Procedure

1. Select the Wiggle Test from the “Diagnostic Test” menu in the EST. Press the **“ENTER”** key to begin test.
2. The technician should wiggle connectors and wires at all suspected problem points. The EST will **“BEEP”** if circuit continuity is broken. It will display all faults found during the test.

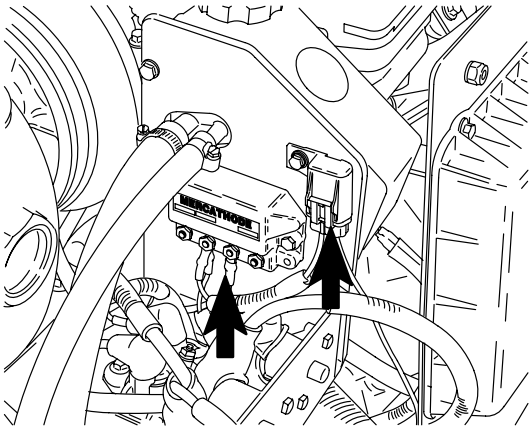
Sensor/Sender Locations

Relays



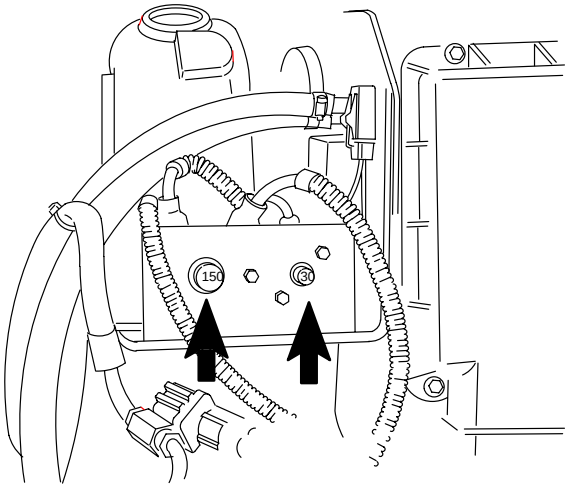
76103

MerCathode Controller And Fuse



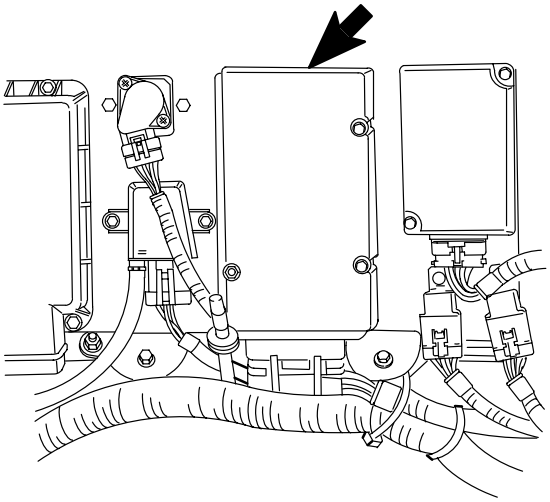
76134

Circuit Breakers



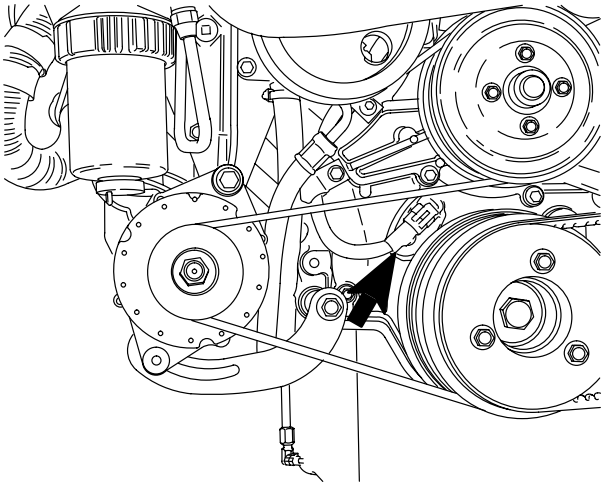
76130

Injector Demand Module (IDM)



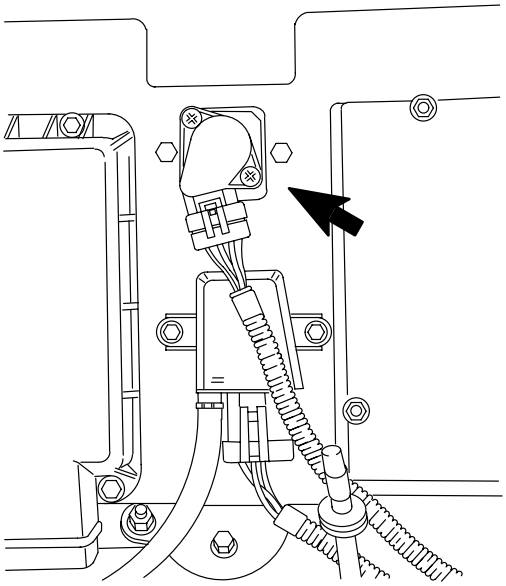
76171

Cam Position Sensor (CMP)



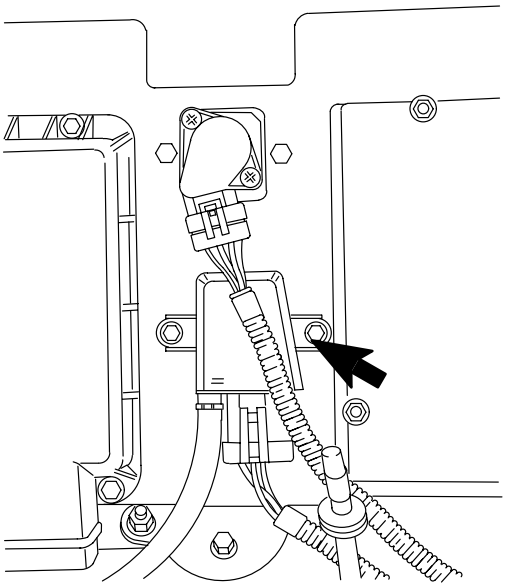
76117

Accelerator Position Switch / Idle Validation Switch (APS/IVS)



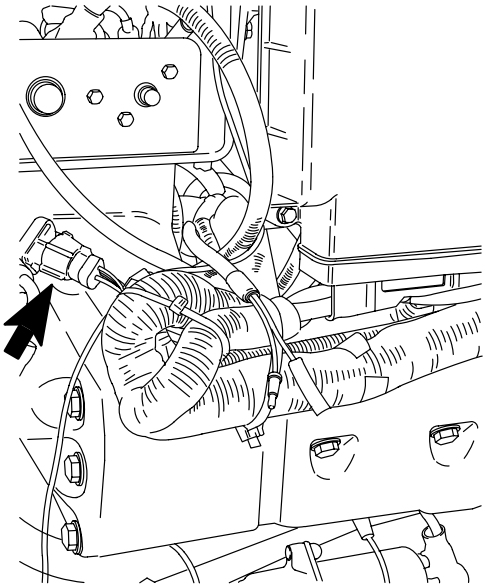
76129

Manifold Absolute Pressure (MAP) Sensor



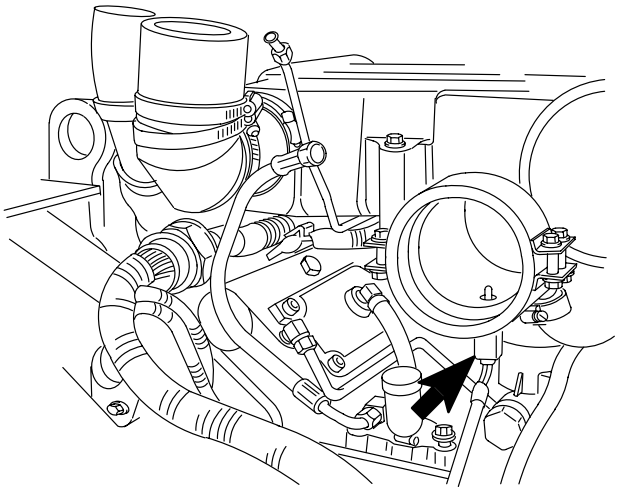
76129

Barometric Pressure (BARO) Sensor



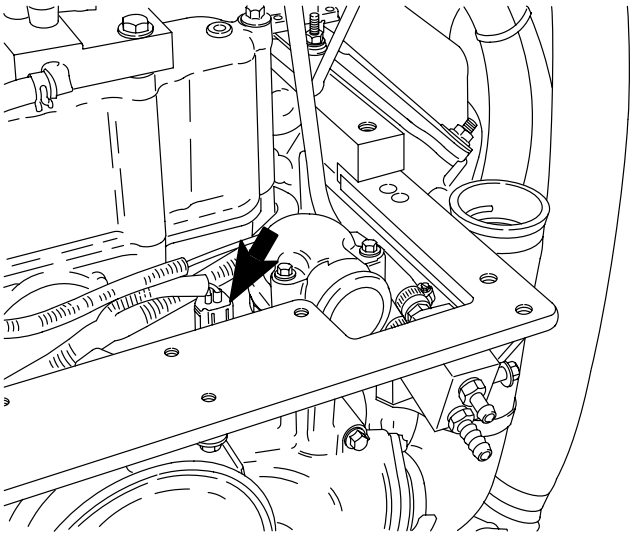
76135

Intake Air Temperature (IAT) Sensor



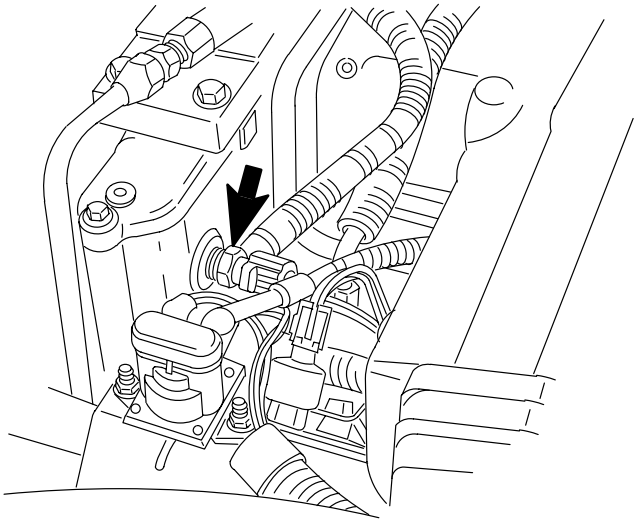
76149

Coolant Temperature (CTS) Sensor



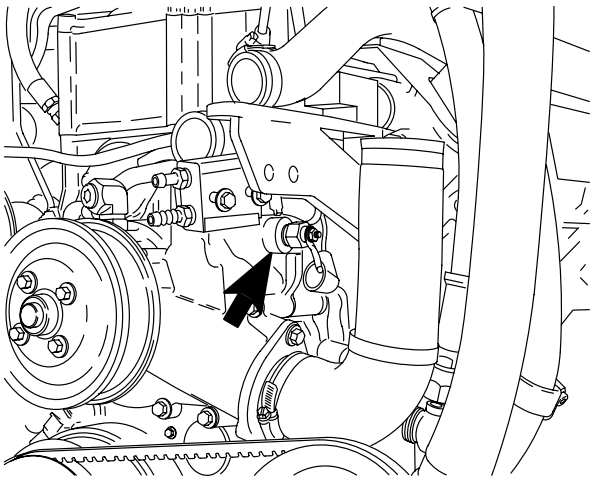
76141

Engine Oil Temperature (EOT) Sensor



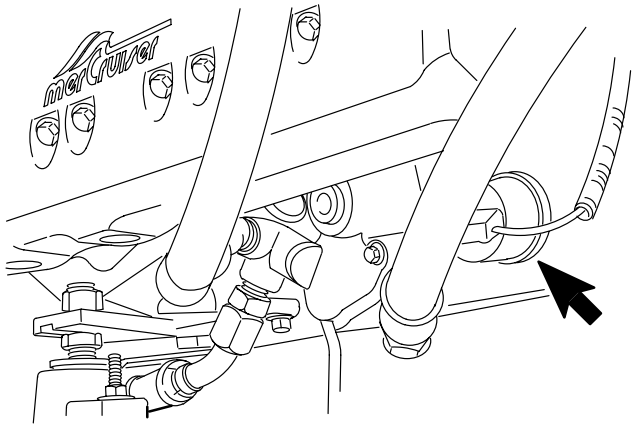
76152

Coolant Temperature Sender (To Gauge)



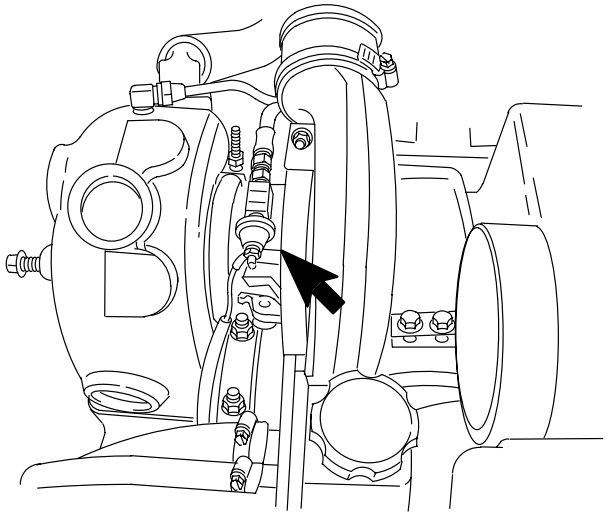
76156

Oil Temperature Sender (To Gauge)



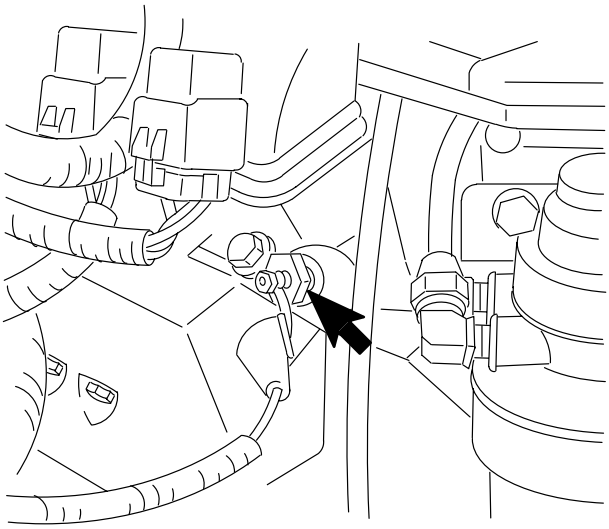
76157

Oil Temperature Switch (To Alarm)



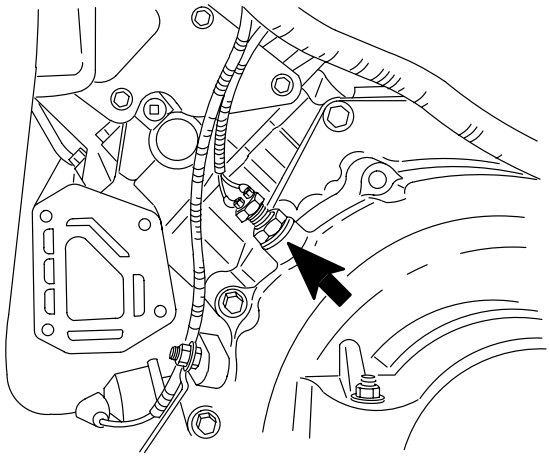
76143

Coolant Temperature Switch (To Alarm)



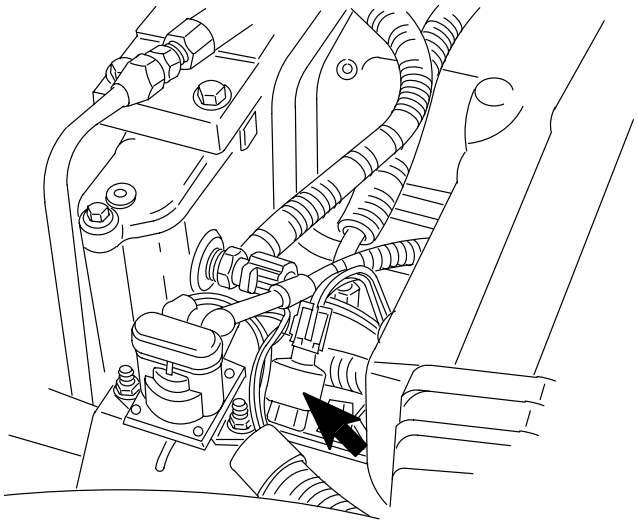
76209

Tachometer Pickup



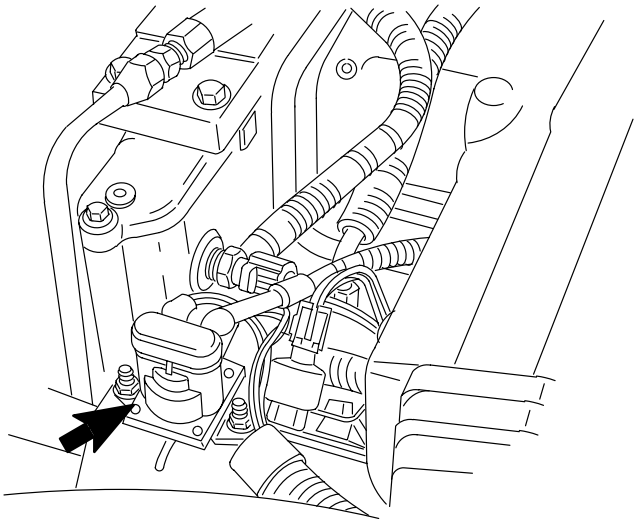
76148

Injection Control Pressure Sensor(ICP)



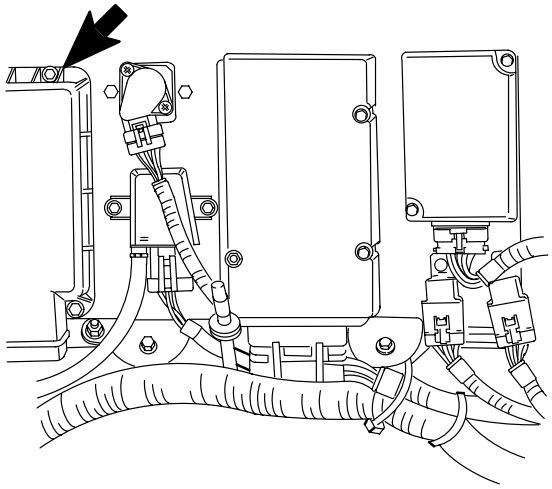
76152

Glow Plug Solenoid



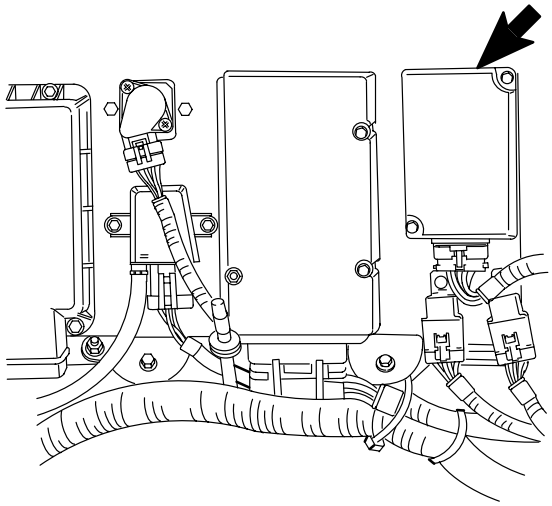
76152

Electronic Control Module (ECM)



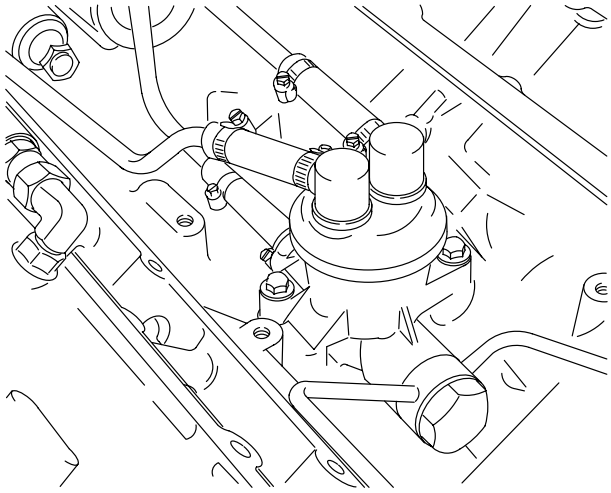
76171

Vessel Personality Module(VPM)



76171

FUEL SYSTEM



76183

5

B

MECHANICAL DIAGNOSTICS

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Hard Start/No Start Diagnostics

Sufficient Clean Fuel

SUFFICIENT CLEAN FUEL

- Check at tank(s), drain sample from fuel filter while cranking engine.

Method	Check
Visual	

PURPOSE

To determine if the fuel system is getting sufficient clean fuel to start and operate the engine.

TEST PROCEDURE

1. Route a hose from the fuel drain tube to a clear container and open the drain.
2. Crank the engine and observe the fuel flowing into the container. Stop cranking the engine when the container is half full.

Fuel flow out of the drain tube should be a steady stream. Insufficient flow could indicate fuel supply or fuel system problem.

3. Inspect fuel in container. It must be clean and free of air, contaminants, water, icing or clouding. The fuel should be straw colored.
4. Check fuel odor for the presence of other fuels such as gasoline or kerosene.

If engine oil is present in the fuel, it may indicate an injector ”O-ring leak and subsequent loss of injection control pressure. If that is suspected, check the injection control pressure during engine cranking. Use the Electronic Service Tool (EST) or follow the procedure outlined later in this section.

NOTE: *Some sediment and water may be present in the fuel sample if the fuel filter has not been serviced or drained for a prolonged period of time. A second sample may be required to determine fuel quality.*

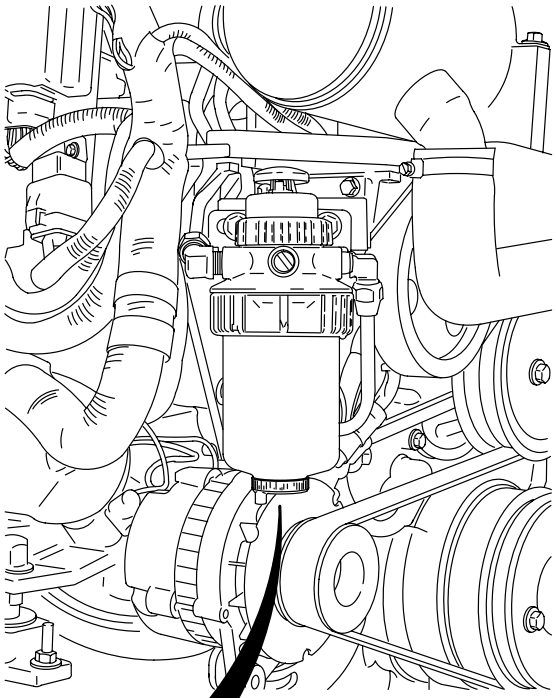
LOW OR NO FUEL - POSSIBLE CAUSES

- No fuel in tank.
- If equipped with an in line fuel valve, it could be shut off.
- Fuel supply line from tank(s) could be broken or crimped.
- Fuel could be waxed or jelled (most likely in cold weather with #2 fuel), the pickup tube in tank could be clogged or cracked. If there is excessive water in the tank, it could freeze preventing the fuel from being drawn to the engine.
- If the vessel is equipped with supplemental filters or water separators, check for plugged filters or leakage that could allow the fuel system to draw air.
- Cloudy fuel indicates that the fuel may not be a suitable grade for cold temperatures. Excessive water or contaminants in the fuel may indicate that the tank and fuel system may need to be flushed and cleaned.

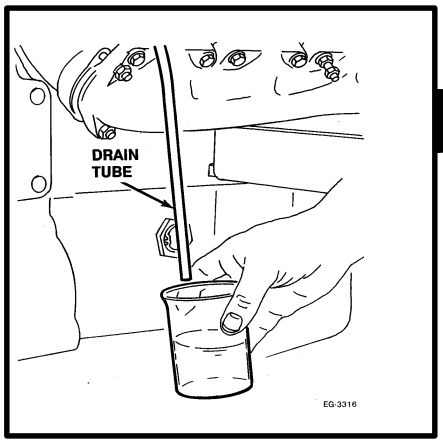
TOOLS REQUIRED

Clear container (approximately 1 quart).

Sufficient Clean Fuel (Cont.)



76102



Visual Inspection

VISUAL INSPECTION				
Fuel	Oil	Coolant	Electrical	Air
Method		Check		
Visual				

PURPOSE

Visual inspection to check the general condition of the engine and to look for obvious causes of hard or no start conditions.

TEST PROCEDURE

1. Inspect entire fuel system for leaks including tank and lines. Inspect fuel lines for damage (kinks and bends).
2. Check high pressure oil lines and high pressure pump in engine “V” for major oil leaks.
3. Inspect entire cooling system, (coolant level in reservoir, hoses, water pump and and heat exchange) for coolant leaks. Check for residue which may have been caused from prior leakage.
4. Inspect engine wiring harness for correct routing and insure that no rubbing or chaffing has occurred. Inspect the 31 pin connector on the engine. Check connections to sensors, relays, actuators and control modules. Inspect battery cable connections for corrosion. **Check the fuses.** All connections should be seated and in good condition, free from damage and corrosion.

POSSIBLE CAUSES

- Loose or leaking fuel supply lines could cause fuel system to lose prime.
- Kinked or blocked fuel supply lines will create restriction to fuel flow.
- Massive fuel or oil leaks may contribute to no start conditions.
- Coolant leaks could indicate serious engine problems.
- Electronic connectors may be damaged or not installed properly causing a no start condition.

NOTE: *The Camshaft Position (CMP) sensor and the Injection Pressure Regulator (IPR) valve are the two most critical electronic components to inspect when the engine fails to start.*

TOOLS REQUIRED

Inspection light.

Checking Engine Oil Level

CHECK ENGINE OIL LEVEL

- Check for contaminants (fuel, coolant)
- Correct grade/Viscosity
- Miles/Hours on oil, correct level
- Check level in reservoir

Method	Check
Visual	

PURPOSE

To determine if the crankcase and oil reservoir contain engine oil of sufficient quantity and quality to enable the injection control pressure system to function properly.

TEST PROCEDURE

1. Check oil level with oil level gauge. If there is no oil or very little oil in the crankcase, the fuel injectors will not operate.

If the oil level on the gauge is over full, it is possible the engine was incorrectly serviced or fuel is diluting the oil and filling the crankcase. If a substantial amount of fuel is in the oil, it will have a fuel odor.

2. Inspect oil for color. A milky white oil indicates possible coolant contamination and will have an ethylene glycol odor.
3. Check service records for correct oil type and viscosity. Single weight or 15W-40 oil is not recommended for cold ambient temperatures. Oil that has had extended drain intervals will have increased viscosity (become thicker) and will make engine cranking more difficult and starting less reliable at temperatures below freezing. Refer to the lube oil chart in the operator's or service manual (section 1B) for the correct oil selection for temperature conditions.
4. The oil level in the oil reservoir should be checked. Remove the inspection plug in top of reservoir to check oil level. Normal oil level is within 1/2 inch below the top of the reservoir. (If the engine has not been operated for some time, oil in the reservoir may drain into the crankcase. The engine may start hard or start and not continue to run.) Filling the reservoir will allow the system to prime faster, facilitating starting.

If the oil level in the reservoir becomes low while the engine is off for a short period of time, it is due to a leaking check valve in the high pressure pump.

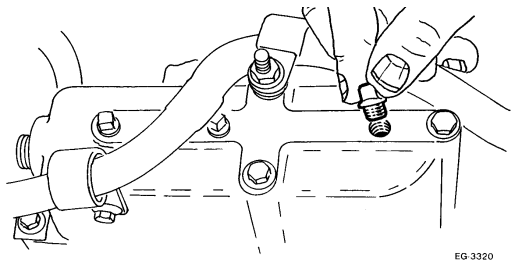
If oil level in the reservoir drops while cranking the engine, it indicates that no oil is being pumped to the reservoir.

POSSIBLE CAUSES

- Oil Level Low - Oil leak, oil consumption, incorrect servicing.
- Oil Level High - Incorrect servicing, fuel dilution from lift pump or defective injector "O" rings.
- Oil Contamination With Coolant - Oil Cooler, head gasket, porosity.
- Low Reservoir Level - Engine built dry (not pressured lubed), prolonged period of not running, leaking check valve in high pressure pump.

TOOLS REQUIRED

1/4" drive ratchet or breaker bar to remove inspection plug.



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Intake/Exhaust Restriction

INTAKE/EXHAUST RESTRICTION

- Inspect air filter and ducts
- Inspect exhaust system
- Inspect exhaust back pressure device

Method	Check
Visual	

PURPOSE

Visual inspection to determine if an intake or exhaust restriction is contributing to a “no start” or “hard start” condition.

NOTE: *A high intake or exhaust restriction may cause a considerable amount of black or blue smoke when starting the engine.*

VISUALLY INSPECT:

1. Air cleaner inlet to assure that it is not restricted.
2. Air cleaner housing, filter element and gaskets for proper installation.

NOTE: *Refer to performance diagnostics for detailed air cleaner restriction information.*

3. Exhaust system for damaged or restricted pipes.

POSSIBLE CAUSES

- Foreign material may restrict air flow at the air cleaner inlet. On engines recently re-paired, rags or cap plugs may have been inadvertently left in the intake system.
- The exhaust pipe may have been damaged or restricted.

TOOLS REQUIRED

None.

EST Tool Fault Codes

EST TOOL-FAULT CODES	
● Install Electronic Service Tool	
Active	
Inactive	

PURPOSE

To determine if the Electronic Control Module (ECM) has detected any fault conditions that would cause a hard or no start condition.

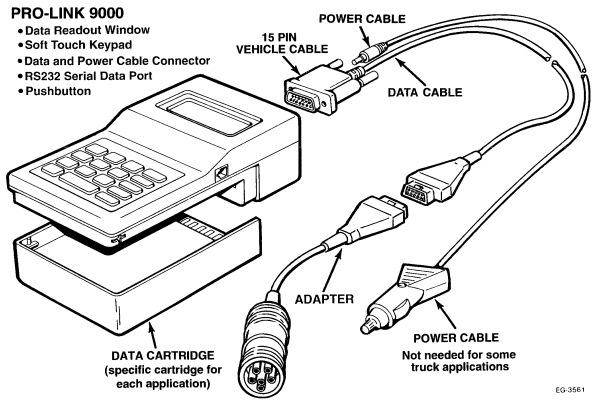
TEST PROCEDURE

NOTE: *Turn all accessories and the ignition off, before connecting EST tool to ATA diagnostic connector.*

Connect the Electronic Service Tool (EST) to the American Trucking Association (ATA) diagnostic connector. The connector is located at instrument panel.

The screen of the reader should light up as soon as the tool is plugged in.

NOTE: *The ATA connector supplies power to operate the EST. The EST will automatically power up as soon as it is plugged into the ata connector. The power cord is not required and is for use only when reading non-volatile memory.*



00000

Turn the ignition switch to the ”ON” position, but **do not start** the engine. This will allow the EST to receive data from the electronic control components. If no data is received, press **”ENTER”** to retry. The information received will be data showing the current status of the engine.

To access the fault codes press the **”FUNC”** key to switch to the main menu.

NAVISTAR MRD
SELECT DESIRED
MENU
[ENGINE] ↔ PRO-LINK

From the main menu select **”ENGINE”** by pressing the “←” key. This will cause the brackets to be placed around the **“ENGINE”** selection. Then press **“ENTER”**.

EST Tool Fault Codes (Cont.)

From the next menu select "**DIAGNOSTIC CODES"**. The selection will have the "↑ ↓" symbol on the screen. This means there are other selections available. By pressing the "↓" key the other selections will display on the screen. Press "↓" key until **"DIAGNOSTIC CODES"** appears on the screen.

NAVISTAR MRD ENGINE MENU		
↑	DIAGNOSTIC CODES	↓

Next press **"ENTER".** This causes the EST to enter the diagnostic codes section. From this point, diagnostic codes can be accessed.

The first option that will appear is **"ACTIVE CODES"**. By selecting this option, the fault codes that are currently occurring or that have occurred since the last key off cycle will be displayed.

NAVISTAR MRD DIAGNOSTIC CODES		
↑	ACTIVE CODES	↓

Press **"ENTER"**. If there are any "Active Codes", the first one will appear on the screen along with a description of the code. If there are any additional codes "Active" the "↑↓" symbol will appear on the screen. Press "↓" key to access additional codes. If there are not any codes "Active", **"NO ACTIVE CODES"** will appear on the screen.

To access "Inactive Codes" press the **"FUNC"** key. This will access the last prior menu selection. Then press the "↓" key to select **"INACTIVE CODES"**. Press the **"ENTER"** key.

NAVISTAR MRD DIAGNOSTIC CODES		
↑	INACTIVE CODES	↓

Inactive codes are faults that have occurred prior to the last key off cycle and are now stored in memory. An "Active Code" will become an "Inactive" code if the key is shut off.

Record all fault codes that are found. If there are any fault codes found, refer to Electronic Control System Diagnostics.

NOTE: *All current fault codes must be repaired and (cleared), before proceeding with further diagnostic testing.*

POSSIBLE CAUSES

Electronic Control Module (ECM) detectable faults which will cause a hard or no start condition are:

- Camshaft Position (CMP) sensor faults.
- Injection Pressure Regulator (IPR) output circuit check fault.
- Fuel Demand Command Signal (FDCS) and Cylinder Identification (CI) output circuit check faults.

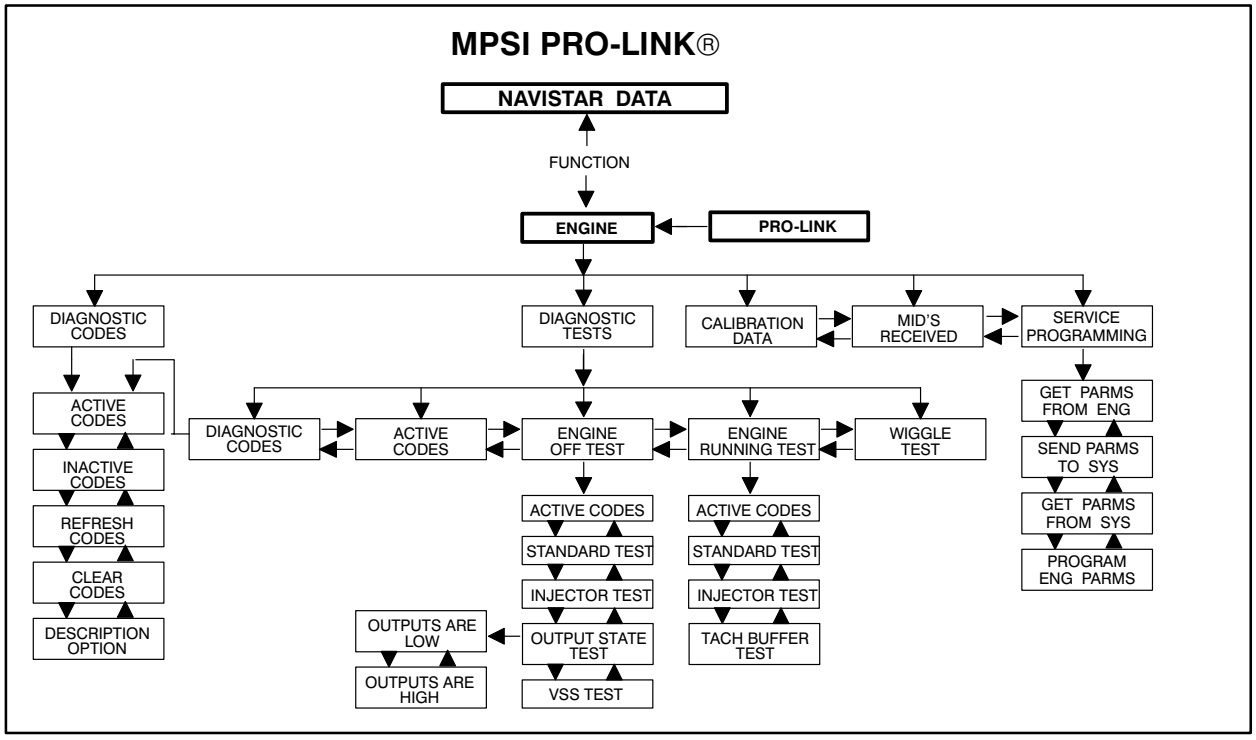
TOOLS REQUIRED

PRO-LINK® 9000 (ZTSE-43661).

SUPPLEMENTAL DIAGNOSTICS

If fault codes are set, refer to Electronic Diagnostic form EGED-135-1 and fault code diagnosis.

EST Tool Fault Codes (Cont.)



EST Tool - Engine Off Tests

EST TOOL-ENGINE OFF TESTS

● Select “Engine Off” test from diagnostic test menu

Faults Found	

□ Repair fault codes before continuing

PURPOSE

To determine if there are any electrical malfunctions that can be detected by the Electronic Control Module (ECM) during an on demand self test.

TEST PROCEDURE

NOTE: *Access “diagnostic codes” menu in est and clear all fault codes before performing engine off tests.*

Access the **“ENGINE OFF TESTS”** in the **“DIAGNOSTIC TESTS”** section of the Electronic Service Tool (EST).

Press the **“FUNC**” key repeatedly, until the main menu appears on the screen.

NAVISTAR MRD
SELECT DESIRED
MENU
[ENGINE] ↔ PRO-LINK

Move the brackets to engine selection by pressing the “←” key, then press **“ENTER”**

Next select the **“DIAGNOSTIC TESTS”** menu by pressing the “↓” key, until **“DIAGNOSTIC TESTS”** is shown on the screen. Press **“ENTER”** to make this selection.

NAVISTAR MRD
ENGINE MENU

↑ DIAGNOSTIC TESTS ↓

Press the “↓” key, until the **“ENGINE OFF TESTS”** is shown on the screen. At this point, press **“ENTER”**

NAVISTAR MRD
DIAGNOSTIC TESTS

↑ ENGINE OFF TESTS ↓

After the **“ENTER”** key is pressed, the EST will command the ECM to perform a [(OCC) Output Circuit Check] self test. During this test, the ECM will test the electrical continuity of the output circuits.

When the test is complete, the screen will display the number of faults found in the self test. If there are any additional faults found, press **“ENTER”** and the faults will be displayed. If there is more than one fault that was found during the test, the “↑↓” symbol will be shown on the screen. Press the “↓” key to access any additional faults.

NOTE: *If fault codes were not cleared before running engine off tests, all IDM faults and associated codes recorded during the test will be stored as “Inactive” codes by the est. to read the codes, access the “inactive” code menu.*

NOTE: *The program in the EST will only allow the engine off tests menu to be accessed once. To repeat engine off tests, select “standard test” to rerun the engine off tests.*

POSSIBLE CAUSES

- Defective electrical components or circuitry.
- Injection Pressure Regulator (IPR) output circuit check fault.
- Fuel Demand Command Signal (FDCS) and Cylinder Identification (CI) output circuit check faults.

TOOLS REQUIRED

PRO-LINK® 9000 (ZTSE-43661).

SUPPLEMENTAL DIAGNOSTICS

If fault codes are set, refer to fault code diagnosis.

EST Tool - Injector Buzz Test

EST-INJECTOR "BUZZ TEST"

NOTE: "Engine Off Test" must be performed first, in order to gain access to the Injector "BUZZ TEST"

- Select "Injector Test" from "The Engine Off Tests"Menu

Faults Found	

PURPOSE

To determine if the injectors are electronically functioning correctly, by energizing each injector in a programmed sequence. The Electronic Control Module (ECM) and Injector Drive Module (IDM) will monitor this test and transmit fault codes if any injector(s) or electrical circuitry are not functioning properly.

TEST PROCEDURE

NOTE: *Access "diagnostic codes" menu in EST and clear all fault codes.*

NOTE: *Engine off test must be performed first in order to access the injector "buzz" test.*

After the **"Engine Off Test"** has been completed, press the "↓" key to access the **"INJECTOR TEST"**. If the tool is not on a menu screen, i.e. displaying of fault codes etc., press the **"FUNC"** key. This will access the **"DIAGNOSTIC TESTS"** menu. Press **"ENTER"** to begin the test.

NAVISTAR MRD
DIAGNOSTIC TESTS

↑ INJECTOR TEST ↓

During this test, the injector solenoids will produce an audible clicking sound when actuated. It is possible to detect a malfunctioning injector(s) by listening for the absence of the solenoid clicking sound.

NOTE: *If fault codes were cleared before the injector "buzz" test, fault codes displayed will be actual faults found during the test. If codes were not cleared before testing, access "inactive" fault codes from diagnostic codes menu to retrieve faults found during this test.*

At the completion of the Injector Test, any faults that have been detected will be displayed. If there is more than one fault the "↑↓" symbol will be displayed. These additional faults can be accessed by pressing the "↓" key.

Record any faults found and refer to the Electronic Control System Diagnostics.

POSSIBLE CAUSES

- Bad wiring harness connection at injector solenoid.
- Open or shorted engine wiring harness to injector(s).
- Defective injector solenoid(s).
- Defective IDM.

TOOLS REQUIRED

PRO-LINK® 9000 (ZTSE-43661).

SUPPLEMENTAL DIAGNOSTICS

If fault codes are set, refer to fault code diagnosis.

STI Switch - Flash Codes

FLASH CODES

- Depress and hold “Engine Diagnostics” switch, then turn the ignition switch to the ”ON” position.

Faults Found	

PURPOSE

To read faults detected by the Electronic Control Module (ECM), if the Electronic Service Tool (EST) is not available or the EST cannot receive “Self Test Input” data due to communications or component failures.

The Self Test Input (STI) switch is located on the instrument panel labeled “ENGINE DIAGNOSTICS”. Depressing the STI switch on the dash while turning the ignition switch to the “ON” position, will signal the ECM to start the Self Test Input diagnostics to check output circuits. If any faults are detected, the ECM will flash the “WARN ENGINE” light to indicate which faults have been detected.

NOTE: *Self test input diagnostics will not flash VPM FAULT CODES.*

TEST PROCEDURE

Depress and hold the STI switch. Turn the ignition switch to the “ON” position. **Do Not Start The Engine.** The ECM will begin to perform the self test to check the output circuits.

When the test is completed, the ECM will flash the red **“OIL/WATER”** light and amber **“WARN ENGINE”** light to signal the fault codes.

NOTE: *Fault codes can be accessed at anytime by turning the ignition switch to the “on” position (DO NOT START ENGINE) and depressing the STI switch.*

To read the fault codes it will be necessary to count the number of times the **“ENGINE WARN”** light flashes. The following sequence of events occur each time the STI switch is depressed to obtain the fault codes:

1. The **“OIL/WATER”** light will flash one time to indicate the beginning of **Active** fault codes.
2. The **“WARN ENGINE”** light will flash repeatedly signaling the active fault codes.

NOTE: *All fault codes are three digits and code 111 indicates “no faults” have been detected.*

3. Count the number of flashes in sequence. At the end of each digit of the code there will be a short pause. Three flashes and a pause would indicate the number 3. Therefore, two flashes, a pause, three flashes a pause, and two flashes a pause would indicate the code 232. If there is more than one fault code, the **“OIL/WATER”** light will flash once indicating the beginning of another active fault code.

After all the active codes have been flashed, the **“OIL/WATER”** light will flash twice to indicate the beginning of **INACTIVE** codes. Count the number of flashes from the **“WARN ENGINE”** light. If there is more than one inactive code, the **“OIL/WATER”** light will flash once in-between each fault code.

After all codes have been sent, the **“OIL/WATER”** light will flash three times indicating “END OF MESSAGE”.

To repeat transmission of fault codes, depress the “ENGINE DIAGNOSTICS” switch which will signal the ECM to resend all stored fault codes.

If fault codes are set, refer to fault code diagnosis.

POSSIBLE CAUSES

- Electronic component or circuitry failures.

TOOLS REQUIRED

None.

EST Tool - Data List

EST TOOL-DATA LIST

- Select and enter the following data as the first three lines in a custom data list
- Monitor the data while cranking the engine for 20 seconds minimum

Data	Spec.	Actual
Bat. voltage	7 volts min.	
Eng. RPM	130 RPM min.	
ICP pressure	800 PSI min.	

☐ If voltage is low, proceed to Sec 5C.

☐ If no RPM is noted, recheck fault codes and proceed to Test 9b.

☐ If ICP pressure is low, refer to system leak tests.

PURPOSE

To determine if the components needed for starting are operating within specifications.

TEST PROCEDURE

IMPORTANT: Test must be performed with Fully Charged Batteries.

To measure engine cranking speed, battery voltage, and Injection Control Pressure (ICP), it may be possible to read the data on the Electronic Service Tool (EST), "DATA LIST", while the engine is cranking. If the voltage drops below 7 volts while cranking, the EST tool will "RESET" back to start-up. If this happens, the tool cannot be used to perform this test. **Refer to Test 9**, "Testing Voltage, RPM and ICP individually".

NOTE: *Turn all accessories and the ignition off, before connecting EST tool to ATA diagnostic connector.*

Connect the EST tool to the American Trucking Association (ATA) diagnostic connector. The screen of the reader should light up as soon as the tool is plugged in.

Turn the ignition switch to the "ON" position. **Do not start the engine.** This will allow the EST to receive data from the electronic control components.

If no data is received press **"ENTER"** to retry. The information received will be data indicating the current status of the engine.

RATED HP	300
RATED RPM	3800
ACTIVE CODES	NO
INACTIVE CODES	NO

Press the "↓" key until "BATT VOLTS" appears on the screen. Continue to press the "↓" key until "BATT VOLTS", is at the top of the screen. Pressing the number **"1"** key, a block dot will appear on line number one.(▮).

▮	BATT VOLTS	12.5
	ENG. OIL TEMP	75 F
	AMBIENT AIR	75 F
	COOLANT TEMP	75 F

This will "Freeze" the "BATT VOLTS" on line one. Now press the "↓" key until "ENGINE RPM" appears on the second line of the screen. Press the number **"2"** key to freeze "ENGINE RPM" on line two of the screen.

▮	BATT VOLTS	12.5
▮	ENGINE RPM	0
	BOOST PSI	0
	BARO IN Hg.	14.4

Continue to press the"↓" key until "INJ CNTL PSI" is on the third line. Then press the number **"3"** key to freeze "INJ CNTL PSI" on line three.

EST Tool - Data List (Cont.)

BATT VOLTS	12.5
ENGINE RPM	0
INJ CNTL PSI	0
FUEL GAL/HR	0.3

The EST is now ready to read the data needed. Crank the engine while observing the data on the screen. If the EST recycles to the entry screen or shuts down, it will be necessary to measure the values separately. If this is required, continue on ECM voltage check.

The battery voltage must be 7 or more volts. If the voltage to the Electronic Control Module (ECM) drops below 7 volts, the ECM will not remain powered up. If the ECM is not receiving power via the ECM relay, the engine cannot be started.

Engine cranking RPM must be sufficient to generate the required Injection Control Pressure to operate the fuel injectors and to create enough compression heat to ignite the fuel.

A “0” RPM indication on the Electronic Service Tool (EST) during engine cranking, indicates the ECM may not be receiving a signal from the Camshaft Position (CMP) sensor. Refer to CMP sensor diagnostics.

If the CMP sensor is inoperative, it must be repaired before continuing. The ECM will not allow the Injector Pressure Regulator (IPR) valve to fully activate without a CMP signal.

If injection control pressure is low, remove the inspection plug in top of the oil reservoir and recheck the oil level. (If the engine has not been operated for some time, the oil may have drained into the crankcase.) If oil level is low, fill the reservoir. If the oil level in the reservoir continues to decline, the engine may not be pumping oil to the reservoir.

IMPORTANT: Test must be performed with Fully Charged Batteries.

POSSIBLE CAUSES

- Low battery voltage. Due to “faulty” batteries, high resistance at battery cable connections or in the wiring to the ECM.
- Defective ECM power relay.
- Blown 15A inline fuse which supplies battery power (voltage) to ECM.
- Blown fuse.
- Low cranking RPM. May be caused by electrical system malfunctions, incorrect oil or extended oil change intervals in cold ambient temperatures.
- No engine RPM indication on EST while cranking the engine. CMP sensor or faulty circuitry to the ECM may cause this condition. Recheck for fault codes after cranking engine.
- A defective high pressure oil pump or pump drive will prevent proper injection control pressure. A defective Injection Pressure Regulator (IPR), or electronic controls for the regulator will cause low injection control pressure.

TOOLS REQUIRED

PRO-LINK® 9000 (ZTSE-43661).

SUPPLEMENTAL DIAGNOSTICS

- Starting system diagnostics. Refer to Electrical section.
- Low voltage at ECM. Refer to Electronic Control Module Power Supply (ECM PWR).
- No Engine RPM indication during engine cranking. Refer to CMP sensor diagnostics.
- No Injection Control Pressure. Refer to Injection Control Pressure (ICP) sensor, IPR valve diagnostics.
- No injection control pressure and no electronic faults. Refer to Injection Control Pressure Test.
- If ICP pressure is low, refer to High Pressure Leakage Tests.

ECM Voltage

ECM VOLTAGE

- Check while cranking engine
- Measure with DVOM
- Breakout box pins 57+ & 40-

Instrument	Spec.	Actual
DVOM 57+ & 40-	7 volts minimum	

- If voltage is low, refer to ECM diagnostics

PURPOSE

To determine if there is sufficient voltage and current to operate the Electronic Control Module (ECM) and Injector Drive Module (IDM). The ECM and IDM require 7 volts minimum to operate and drive the injectors. This is an alternate method to be used if the Electronic Service Tool (EST) is unavailable or fails to function properly. Insufficient electrical power from the batteries or an electronic failure may inhibit the EST from receiving diagnostic data.

TEST PROCEDURE

IMPORTANT: Tests must be performed with Fully Charged Batteries.

Voltage measurement at battery:

1. Connect a DVOM (Digital Volt Ohm Meter) across the battery terminals.
2. Turn all accessories off and turn the ignition switch to the “ON” position.
3. Wait for the glow plug system to cycle, then crank the engine.

Record the lowest voltage obtained during engine cranking. If the voltage is below 7 volts, the IDM and ECM power relays may be resetting due to the lack of voltage and current from the batteries or a problem exists in the starting system.

If voltage is within specification, perform **Voltage Measurement At The ECM Relay.**

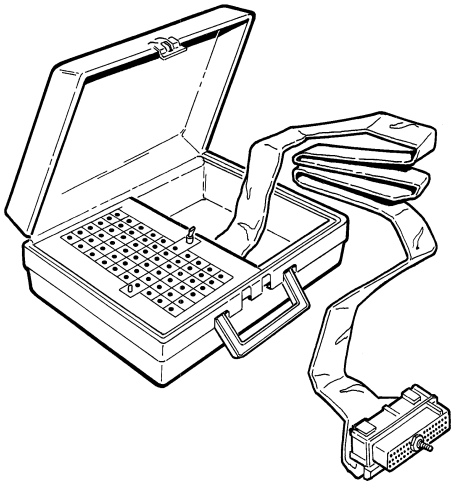
Voltage measurement at the ECM relay:

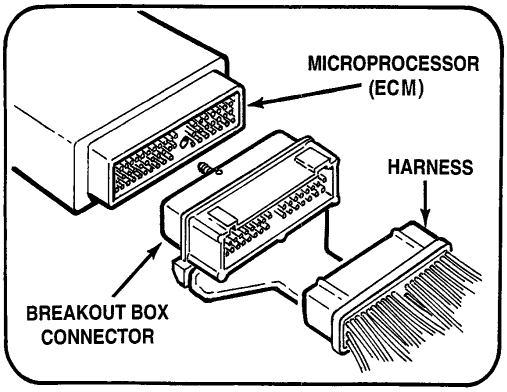
The ECM power relay is located on the engine cowl and mounted on a bracket over the IDM.

1. Connect a DVOM (+ lead) to terminal 87(wire 97AR) of the ECM relay and the (- lead) to battery ground.
2. Turn all accessories off and turn the ignition switch to the “ON” position.
3. Wait for the glow plug system to cycle, then crank the engine.
4. Observe and record voltage while engine is cranking.

If no voltage is present at terminal 87(wire 97AR), refer to Electronic Control Module Power Supply (ECM PWR). If voltage is 7 or more volts, proceed with voltage check using the breakout box.

ECM Voltage (Cont.)





Voltage measurement at ECM with breakout box:

1. Remove the 60 way connector from the ECM. Attach the adapter of the breakout box to the ECM and secure the bolt in the center of the adapter.
2. Reattach the 60 way connector to the adapter and secure the bolt in the center of the plug to the adapter.
3. Connect the positive lead of the voltmeter to terminal 57 and the negative lead to terminal 40 on the breakout box.
4. Turn the ignition switch to the “ON” position. Wait for the glow plug system to cycle, then crank the engine. Record the lowest voltage observed while cranking engine.
5. If voltage is lower than 7 volts, repair the ECM power feed circuit. Refer to Electronic Control Module Power Supply (ECM PWR).

POSSIBLE CAUSES

- Low battery voltage. Due to “faulty” batteries, high resistance at battery cable connections or defective starter.
- Low or no battery voltage to the ECM. May be due to high resistance or an open circuit in the power feed circuit to the ECM or it’s power relay. The ECM power circuit fuse, may be open or the ECM power relay may be defective.

TOOLS REQUIRED

DVOM and breakout box.

SUPPLEMENTAL DIAGNOSTICS

- Refer to Electronic Control Module Power Supply (ECM PWR).

Engine Cranking RPM

ENGINE CRANKING RPM

- Minimum 130 RPM engine cranking speed for 20 seconds.
- Breakout box pins 34+ & 46- with Fluke 88

Instrument	Spec.	Actual
Fluke 88 34+ & 46-	130 RPM minimum	

- ☐ If no RPM is noted, recheck fault codes

PURPOSE

To determine if engine cranking speed is high enough to start the engine. This is an alternate method to be used if the Electronic Service Tool (EST) is unavailable or fails to function properly. Insufficient electrical power from the batteries or an electronic failure may inhibit the EST from receiving diagnostic data.

TEST PROCEDURE

IMPORTANT: Test must be performed with Fully Charged Batteries.

Engine cranking RPM must be sufficient to generate the required Injection Control Pressure to operate the fuel injectors and to create enough compression heat to ignite the fuel.

A "0" RPM indication on the Electronic Service Tool (EST) during engine cranking, may indicate the ECM is not receiving a signal from the Camshaft Position (CMP) sensor. Refer to CMP sensor diagnostics, in Electronic Control System Diagnostics, Section 3.5.

If the CMP sensor is inoperative, it must be repaired before continuing. The ECM will not allow the Injector Pressure Regulator (IPR) valve to fully activate without a CMP signal.

Checking cranking RPM with breakout box:

1. Remove the 60 way connector from the Electronic Control Module (ECM). Attach the adapter of the breakout box to the ECM and secure the bolt in the center of the adapter.
2. Reattach the 60 way connector to the adapter and secure the bolt in the center of the plug to the adapter.
3. Connect the (+ lead) of DVOM to terminal 34 and the (- lead) to terminal 46. Select the DC voltage scale and press the "RPM" button.
4. Crank the engine while observing the DVOM. A minimum of 130 RPM is necessary to start the engine.
5. Record cranking engine RPM on diagnostic form.

NOTE: *If no engine RPM is measured with the Fluke 88, check for additional fault codes. Refer to tests 5 & 7 and electronic control system diagnostics section, for Camshaft Position (CMP) sensor diagnostics.*

POSSIBLE CAUSES

- Low cranking RPM. Starting system electrical malfunctions. Incorrect oil type or extended oil change intervals in cold ambient temperature conditions.
- No engine RPM. Poor connection at CMP sensor wiring harness connector, wiring harness to sensor open or shorted or CMP sensor is defective.

TOOLS REQUIRED

Size DVOM and breakout box (ZTSE-4346).

SUPPLEMENTAL DIAGNOSTICS

- Refer to CMP sensor diagnostics, in Electronic Control System Diagnostics.

Injection Control Pressure

INJECTION CONTROL PRESSURE

- Check during engine cranking. (min. 130 RPM)
- Measure with w/breakout box pins 27+ and 46- or breakout “tee” signal (green) & ground (black)

Instrument	Spec.	Actual
DVOM 27+ & 46-	1 to 4 volts	

☐ If less than 1 volt, recheck oil level in reservoir.

If ICP pressure is low, refer to system leakage tests.

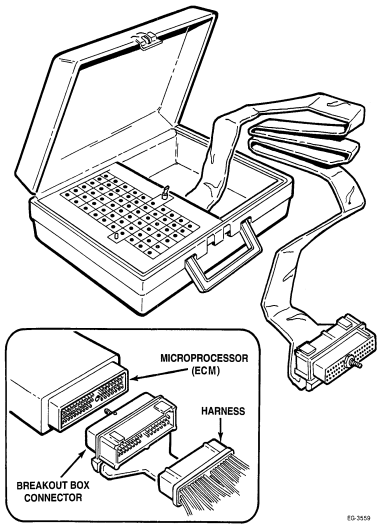
PURPOSE

To determine if the injection control pressure system is supplying sufficient oil pressure to start and operate the engine. This is an alternate method to be used if the Electronic Service Tool (EST) is unavailable or fails to function properly. Insufficient electrical power from the batteries or an electronic failure may inhibit the EST from receiving diagnostic data.

TEST PROCEDURE

Measuring Injection Control Pressure using breakout box:

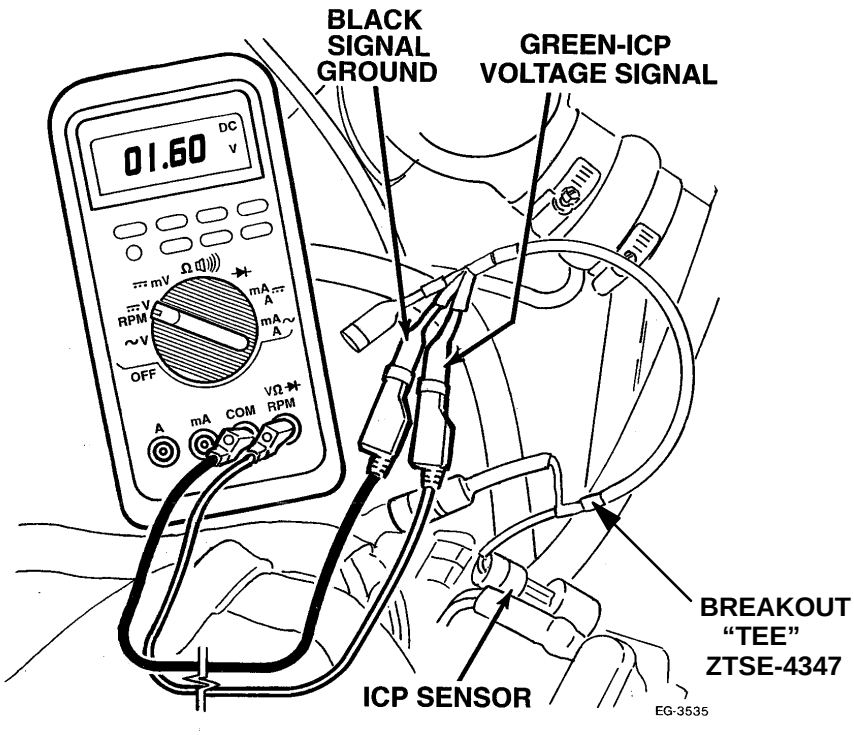
1. Remove the 60 way connector from the ECM. Attach the adapter of the breakout box to the ECM and secure the bolt in the center of the adapter.



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2. Reattach the 60 way connector to the adapter and secure the bolt in the center of the plug to the adapter.
3. Connect the positive lead of the DVOM to terminal 27 and the negative lead to terminal 46.
4. Crank the engine while observing the DVOM and record the injection control pressure voltage signal on diagnostic form. **If Injection Control Pressure (ICP) is low, refer to High Pressure Leakage Tests.**

Injection Control Pressure (Cont.)



ALTERNATE METHOD OF MEASURING INJECTION CONTROL PRESSURE USING (BREAKOUT "TEE")

1. Remove engine harness connector at ICP sensor.
2. Connect the breakout "TEE" to the removed engine harness connector and the ICP sensor.
3. Connect DVOM leads (+Green, -Black) to the breakout "TEE" as shown.
4. Crank engine and observe DVOM voltage reading. Record reading on diagnostic form. If voltage is low, recheck oil level in reservoir to confirm the reservoir contains a sufficient supply of oil to enable the injection control system to function properly. **If oil level is OK, proceed to High Pressure Leakage tests.**

High Pressure Leakage Tests

ISOLATE RIGHT CYLINDER HEAD

Remove high pressure hose from the right cylinder head. Use an Aero Equip size 6 flare plug and install into the high pressure hose to block it off. Crank the engine and monitor the Injection Control Pressure (ICP) signal.

⚠CAUTION

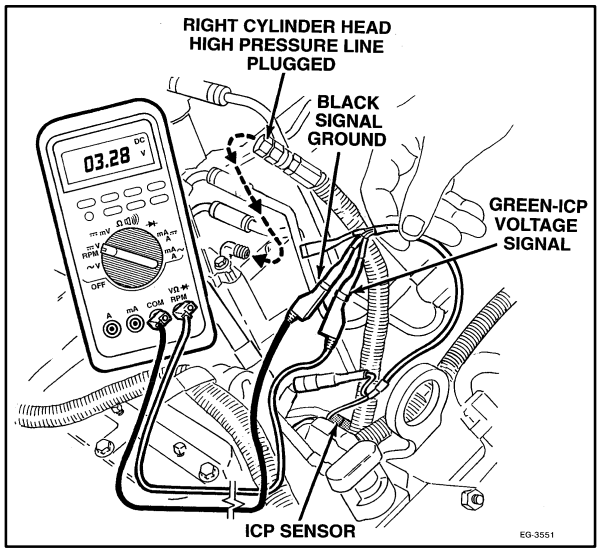
The Engine May Start!

If the engine fails to start, refer to procedure on Isolating Left Cylinder Head. If the engine starts or the ICP pressure is now within specifications, the injection control pressure leak has been isolated to the right cylinder head.

1. Remove flare plug from the high pressure supply hose and reconnect hose to right cylinder head.
2. Remove valve cover on right cylinder head.
3. Crank the engine and inspect the injector body and bore area for leakage. If no leakage is detected, perform ICP Leakage Test page.

⚠CAUTION

Oil is under high pressure.



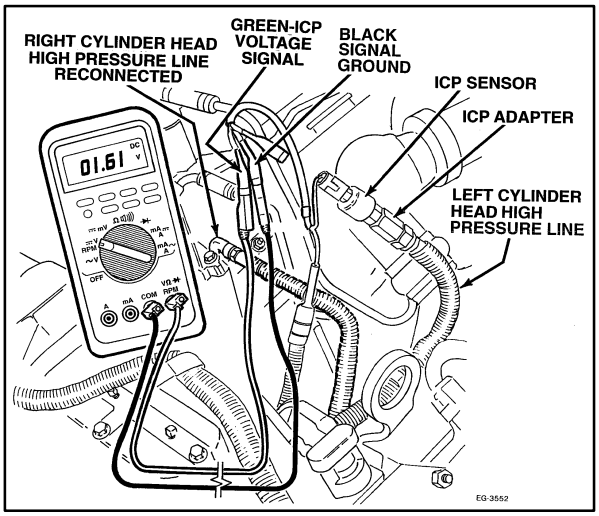
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ISOLATE LEFT CYLINDER HEAD

Remove the plug (from previous step) in the right cylinder head high pressure hose and reconnect hose to cylinder head. Remove the high pressure hose from the left cylinder head. Remove the ICP sensor and assemble it to the ICP adapter. Install the ICP sensor/adapter onto the high pressure hose. Crank the engine and monitor the ICP signal.

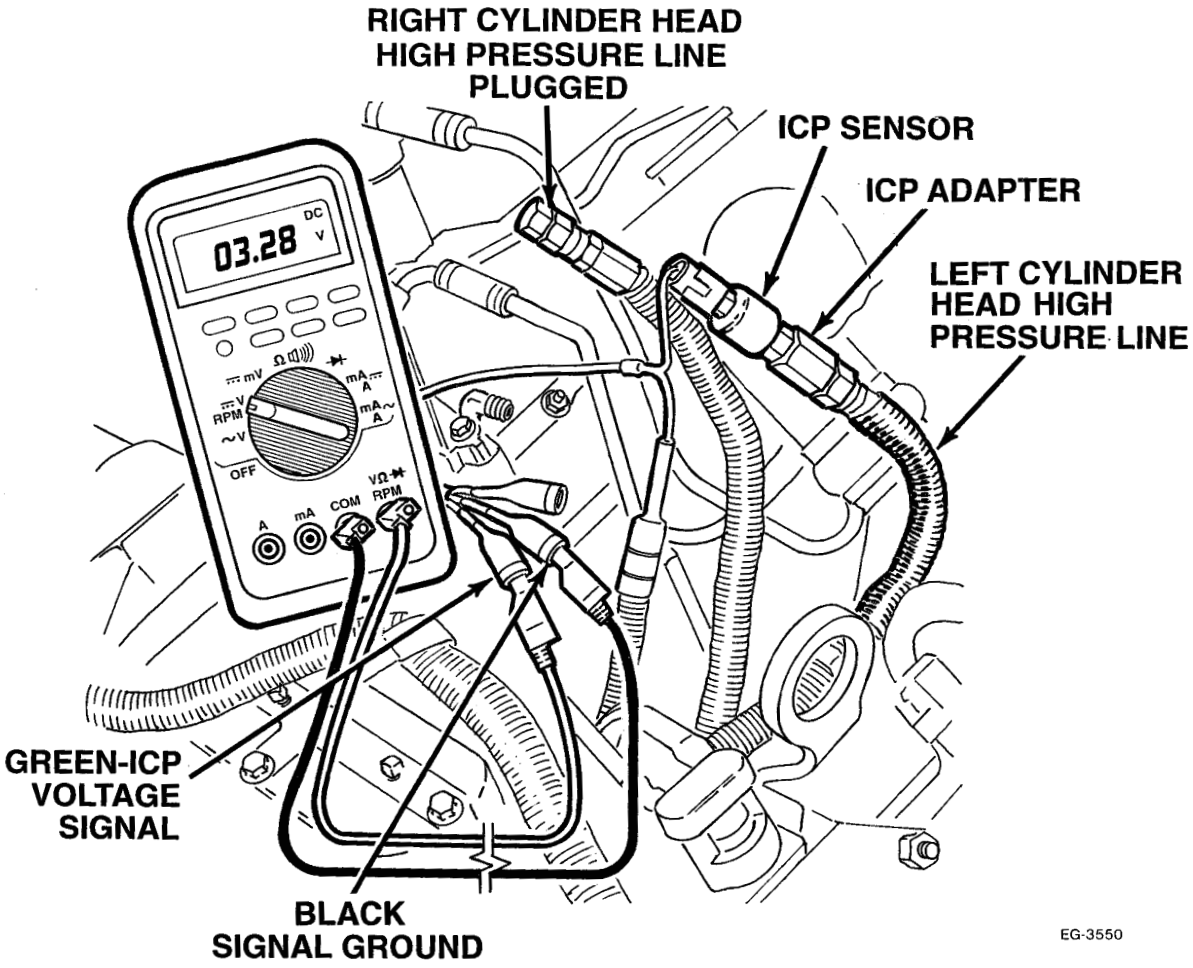
NOTE: *If the ICP pressure is not within specification, proceed to IPR and High Pressure Pump Test page.*

If the engine starts, or the ICP pressure is now within specifications, the injection control pressure leak has been isolated to the left cylinder head. Reattach the left side high pressure hose. Remove left valve cover and crank the engine. Inspect the injector body and bore area for oil leakage. If no leakage is detected, perform ICP Leakage Test page.



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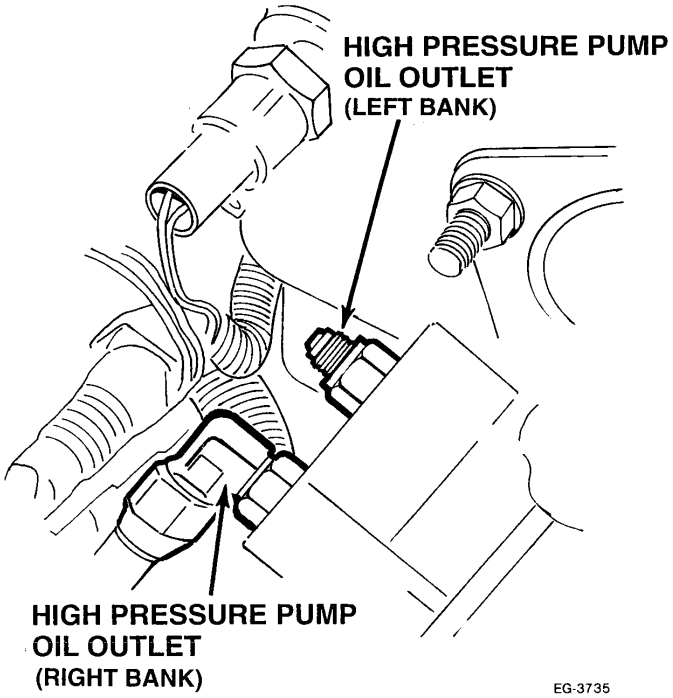
High Pressure Leakage Tests (Cont.)



IPR AND HIGH PRESSURE PUMP TEST

If injection control pressure is still low after isolating both cylinder heads, leave the ICP sensor adapter in the left hose and reinstall the flare plug to block the right high pressure hose and crank the engine. This has effectively deadheaded the high pressure pump. If pressure is still not developed, inspect the IPR (Injection Pressure Regulator) valve for debris and/or replace with a known good valve and retest. If pressure is still low, check the high pressure pump and drive gear. The gear may be loose or the pump may be defective.

ICP Leakage Test



1. Reconnect all high pressure oil lines disconnected in the process of isolating the cylinder head which is causing a loss of ICP pressure.
2. Remove the high pressure supply line of the suspect leaking cylinder head at the high pressure pump.
3. Connect a regulated air supply to the high pressure supply oil line removed in the previous step.
4. Apply 100 psi of pressure from the regulated air source and inspect for leakage around the injectors.
5. With the fuel lines removed from the fuel regulator block, inspect for oil leakage out of each of the disconnected fuel lines. If oil is seeping out of the disconnected fuel lines remove all injectors in the cylinder head being tested and inspect injectors for worn O-rings or obvious damage.

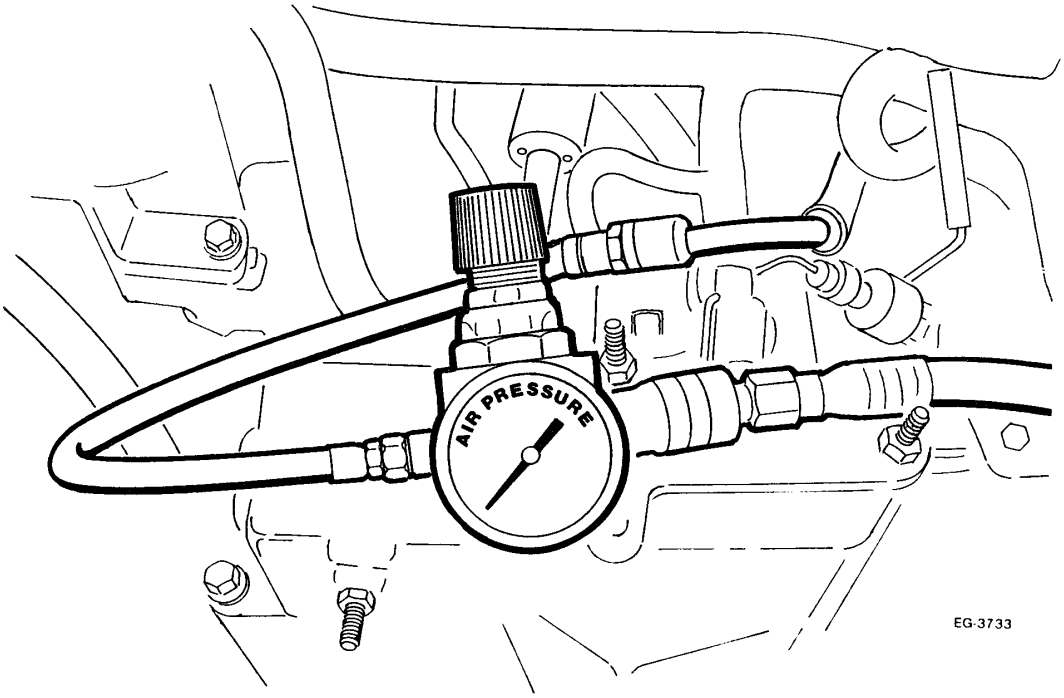
If leakage is observed at an injector, remove and inspect injector for obvious damage or worn O-rings.

If no leakage is present, perform Injector “Buzz” test with air pressure still applied. Observe oil discharge from each of the injectors. Oil discharge should be equal from all injectors. If excess oil is discharged-from an injector(s), the injector(s) may be defective.

6. If it is difficult to determine which injector(s) are leaking remove air supply and regulator from the high pressure oil supply hose and:
   a Connect an **automotive cylinder leak tester** to the high pressure supply hose and apply air pressure via the cylinder leak tester.
   b Conduct an Injector “Buzz” test and observe the percent cylinder leakage while each injector is activated. Remove and inspect injectors which exhibit a greater amount of leakage compared to the others.
   c If none of the injectors indicate an excessive amount of leakage, remove all injectors. Inspect all O-rings for wear and damage. All O-rings should be replaced.

If oil was entering the fuel system, drain fuel tanks and dispose of the contaminated fuel properly.

ICP Leakage Test (Cont.)



POSSIBLE CAUSES:

- No oil in engine.
- Oil reservoir leak down (possibly through high pressure pump check valve.
- Defective high pressure pump
- Injector “O” ring leak.
- Injector body leak.
- IPR valve stuck open.
- Pump drive gear loose or damaged.

TOOLS REQUIRED:

DVOM, ICP sensor breakout “T” (ZTSE-4347), ICP adapter and an Aero Equip size 6 flare plug.

SUPPLEMENTAL DIAGNOSTICS

- Camshaft Position (CMP) sensor diagnostics, in Electronic Control System Diagnostics.

Fuel Pump Pressure

FUEL PUMP PRESSURE

- Measure at regulator block
- Minimum 130 RPM cranking speed for 20 seconds

Instrument	Spec.	Actual
0 - 160 PSI Gauge	20 PSI minimum	

☐ **If pressure is low, replace fuel filter and retest.**

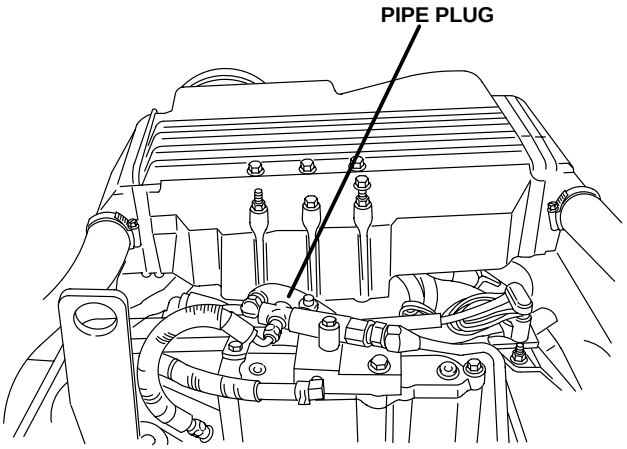
PURPOSE

To determine if fuel pressure is sufficient to start and operate the engine.

NOTE: *If the fuel filter is equipped with a water-in-fuel probe, check to determine if the water- in- fuel lamp has been illuminated during operation.*

TEST PROCEDURE

1. Remove 1/8” pipe plug located on the fuel regulator block. Install 1/8 inch (3 mm) pipe fitting in place of the pipe plug.



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2. Connect a line from the fitting to the 0-160 PSI gauge of the Model D-200 Pressure Test Kit.
3. Measure fuel pressure by cranking engine for 20 seconds and observing maximum pressure. Record pressure on diagnostic form and compare to specifications. **If fuel pressure is low, change the fuel filter and retest.**

NOTE: *It may take a number of crank cycles to purge the air out of the fuel system.*

POSSIBLE CAUSES

- A fuel filter could cause high restriction and low fuel pressure because of dirt or fuel jelling in cold ambient temperatures. Change filter and retest.
- A kinked or severely bent fuel supply line or blockage at the pickup tube could cause restriction and therefore low fuel pressure.
- A loose fuel line on the suction side of the fuel system could cause air to be ingested into the system and cause low fuel pressure.
- The fuel pump could have internal damage, e.g. ruptured diaphragm, seized plunger or leaking check valves.

TOOLS REQUIRED

Model D-200 Pressure Test Kit (ZTSE-2239) (0 to 160 PSI fuel pressure gauge), appropriate line with 1/8” NPT fitting.

Glow Plug System

GLOW PLUG SYSTEM
Relay Operation

- Install a voltmeter to the glow plug feed terminal (terminal w/2 wires)
- Turn key to “ON” position, measure “ON” time.
- Verify sufficient glow plug “ON” time using voltmeter to verify glow plugs are receiving the required voltage within the specified time.

(Dependent upon coolant temperature, battery voltage and altitude)

	Spec.	Actual
Relay On Time	10 - 120 seconds	
Voltage	9 - 12 Volts	

(Relay may not cycle on, if engine is at operating temperature)

GLOW PLUG OPERATION

- Remove all glow plug/injector connectors.
- Measure glow plug resistance to ground (-).
- Measure GP harness resistance to relay.

Glow Plug Number	Plug to Ground .1 to 6 Ohms	Harness to Relay < 1 Ohm
#1		
#3		
#5		
#7		
#2		
#4		
#6		
#8		

PURPOSE

To determine if the glow plug system is operating sufficiently to start a cold engine.

TEST PROCEDURE:

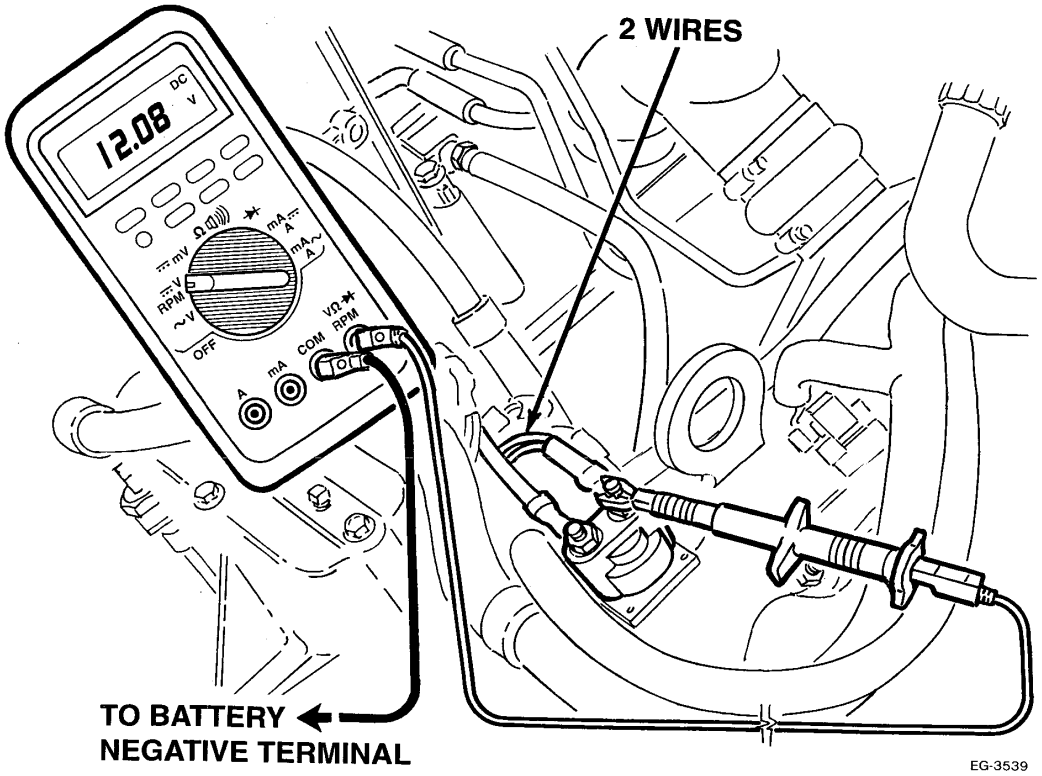
Glow Plug “ON” Time:

Connect a DVOM to the glow plug feed terminal (terminal with 2 wires) on the glow plug relay. The DVOM will verify that the glow plugs are receiving the required voltage (9-12v) for the specified amount of time. Turn the ignition key to the “ON” position.

DO NOT ATTEMPT TO START ENGINE. Note the time in seconds from when the ignition key is turned “ON” until the glow plug relay de-engergizes (0 volts indication on the DVOM).

NOTE: *Glow plug “ON” time will be affected by engine coolant temperature, battery condition and altitude.*

Glow Plug System (Cont.)

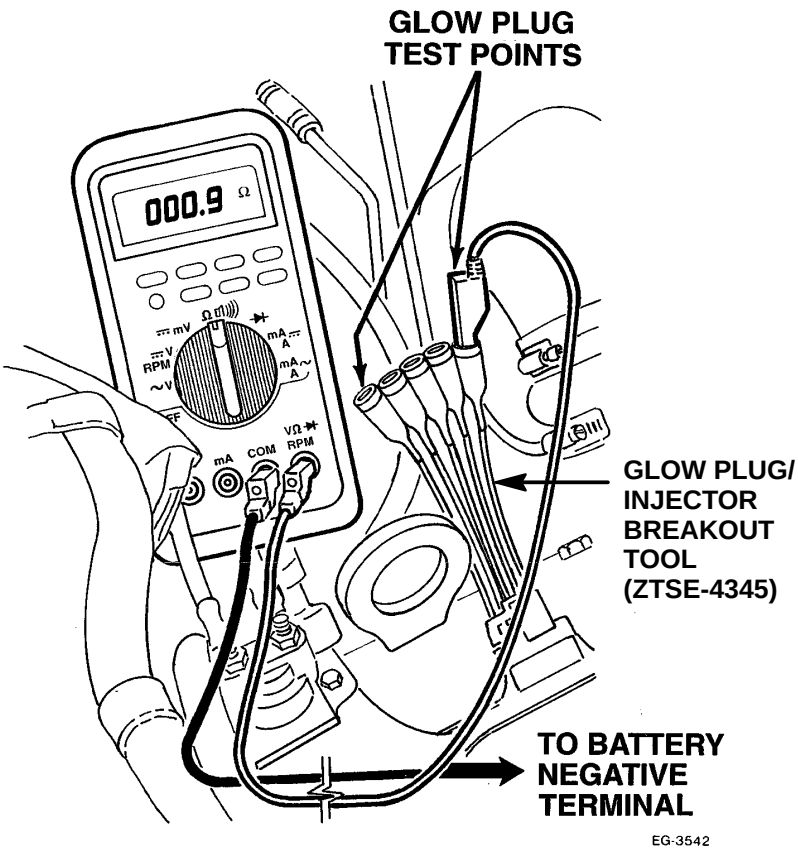


If no voltage is present, check for voltage at the other large terminal of the glow plug relay. If no voltage present, refer to glow plug system diagnostics in Electronic Control System Diagnostics.

POSSIBLE CAUSES

Insufficient glow plug on time will not allow enough heat to accumulate in the combustion chamber to easily facilitate starting. If the glow plug system "ON" time does not meet specifications the problem may be:

- Faulty wire harness connection.
- Poor ground connection.
- Defective glow plug relay.
- ECM in default
- ECM defective.



TEST PROCEDURE:

Glow Plug Resistance To (Battery Ground (-) Terminal)4.

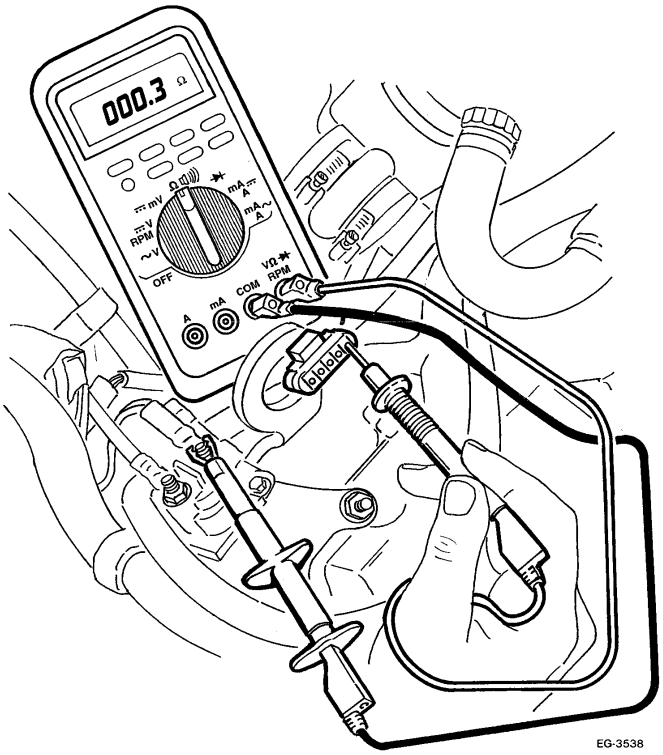
Disconnect the (4) glow plug/injector harness connectors from the valve cover gasket (harness).

NOTE: *Incorrect measurements will result, if all glow plug/injector harness connectors are not disconnected.*

Connect pigtail tool to each valve cover harness connector to measure glow plug resistance to (ground) battery negative terminal. Record resistance measurements on diagnostic form. A resistance measurement of .1 to 6 ohms indicates a good glow plug.

If the glow plug resistance to ground is high the most likely causes are:

- Open UVC (under valve cover) harness.
- Open glow plug.



TEST PROCEDURE:

Glow Plug Harness Resistance To Relay:

Measure resistance from the engine harness connector to the glow plug feed terminal on the glow plug relay.

NOTE: *Incorrect measurements will result, if all glow plug/injector harness connectors are not disconnected.*

TOOLS REQUIRED

DVOM, Glow Plug/Injector Breakout Tool (ZTSE-4345) and Stop Watch or equivalent.

Performance Diagnostics

Check Engine Oil Level

CHECK ENGINE OIL LEVEL

- Check for contaminants (fuel, coolant)
- Correct grade/Viscosity

Method	Check
Visual	

☐ If idle quality is poor after extended running, refer to “Injection Control Pressure Test”.

PURPOSE

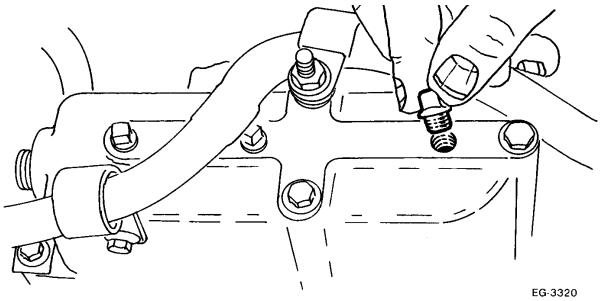
To determine if the crankcase and oil reservoir contain engine oil of sufficient quantity and quality to enable the injection control pressure system to function properly.

TEST PROCEDURE

1. Check oil level with oil level gauge. If there is no oil or very little oil in the crankcase the fuel injectors will not operate.

If the oil level on the gauge is over full, it is possible the engine was incorrectly serviced or fuel is diluting the oil and filling the crankcase. If a substantial amount of fuel is in the oil, it will have a fuel odor.

2. Inspect oil for color. A milky white oil indicates possible coolant contamination and will have an ethylene glycol odor.
3. Check service records for correct oil type and viscosity, for the temperature (environment) that engine is operating in. Single weight or 15W 40 oil is not recommended for cold ambient temperatures. Oil that has had extended drain intervals will have increased viscosity (become thicker) and will make engine cranking more difficult and starting less reliable at temperatures below freezing. Refer to lube oil chart in the operator’s manual or service manual section 1B for the correct oil selection for temperature conditions.
4. Check oil level in reservoir.



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POSSIBLE CAUSES

- Oil level low - Oil leak, oil consumption, incorrect servicing.
- Oil level high - Incorrect servicing, fuel dilution from lift pump or defective injector “O” rings.
- Oil Contamination with Coolant Oil Cooler, head gasket, porosity.
- Low reservoir level - Engine built dry (not pressured lubed), prolonged period of not running, leaking check valve in high pressure pump.

TOOLS REQUIRED

1/4” drive ratchet or breaker bar to remove inspection plug.

Sufficient Clean Fuel

SUFFICIENT CLEAN FUEL

- Check at tank(s), drain sample from fuel filter while cranking engine.

Method	Check
Visual	

PURPOSE

To determine if the fuel system is getting sufficient clean fuel to start and operate the engine.

TEST PROCEDURE

1. Route a hose from the fuel drain tube to a clear container and open the drain.
2. Crank the engine and observe the fuel flowing into the container. Stop cranking the engine when the container is half full.

Fuel flow out of the drain tube should be a steady stream. Insufficient flow could indicate fuel supply or fuel system problem.

3. Inspect fuel in container. It must be clean and free of air, contaminants, water, icing or clouding. The fuel should be straw colored. Fuel dyed red or blue indicates an off highway fuel.
4. Check fuel odor for the presence of other fuels such as gasoline or kerosene.

If engine oil is present in the fuel, it may indicate an injector O-ring leak and subsequent loss of injection control pressure. If that is suspected, check injection control pressure during engine cranking. Use the Electronic Service Tool (EST) or follow procedure outlined in this section**.**

NOTE: *Some sediment and water may be present in the fuel sample if the fuel filter has not been serviced or drained for a prolonged period of time. A second sample may be required to determine fuel quality.*

LOW OR NO FUEL POSSIBLE CAUSES

- No fuel in tank.
- If equipped with a inline fuel valve, it could be shut off.
- Fuel supply line from tank(s) could be broken or crimped.
- Fuel could be waxed or jelled (most likely in cold weather with #2 fuel), the pickup tube in tank could be clogged or cracked. If there is excessive water in the tank, it could freeze preventing the fuel from being drawn to the engine.

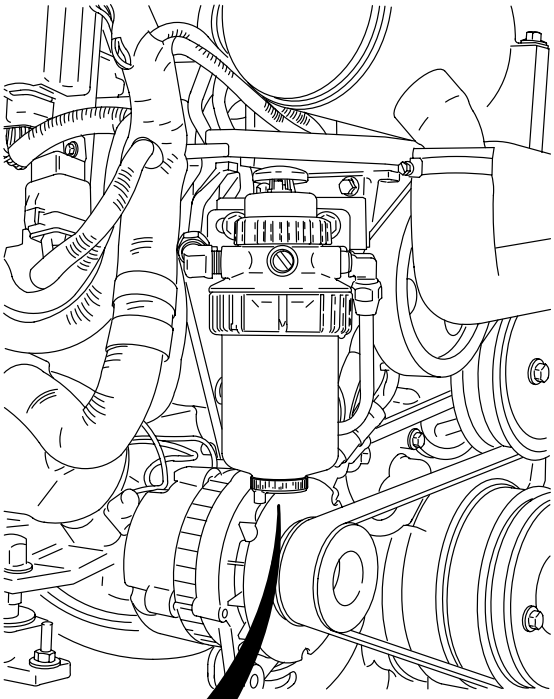
If the vessel is equipped with supplemental filters or water separators, check for plugged filters or leakage that could allow the engine to draw air.

Cloudy fuel indicates that the fuel may not be a suitable grade for cold temperatures. Excessive water or contaminants in fuel may indicate that the tank and fuel system may need to be flushed and cleaned.

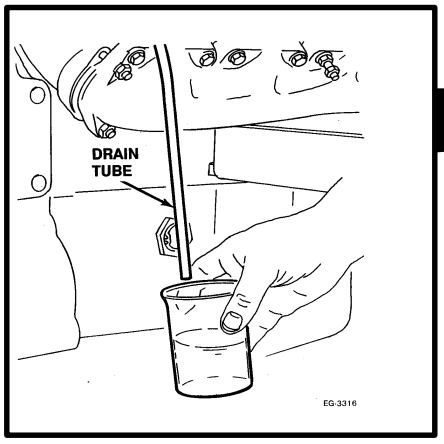
TOOLS REQUIRED

Clear container (approximately 1 quart).

Sufficient Clean Fuel (Cont.)



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EST Tool Fault Codes

EST TOOL-FAULT CODES	
● Install Electronic Service Tool	
Active	
Inactive	

PURPOSE

To determine if the Electronic Control Module (ECM) has detected any fault conditions that would cause a hard or no start condition.

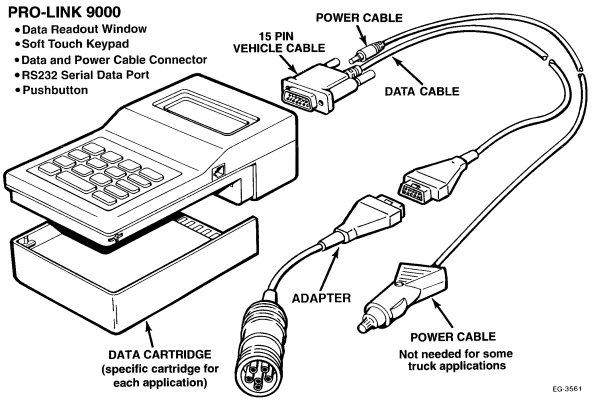
TEST PROCEDURE

NOTE: *Turn all accessories and the ignition off, before connecting EST tool to ata diagnostic connector.*

Connect the Electronic Service Tool (EST) to the American Trucking Association (ATA) diagnostic connector. The connector is located at instrument panel.

The screen of the reader should light up as soon as the tool is plugged in.

NOTE: *The ATA connector supplies power to operate the est. The EST will automatically power up as soon as it is plugged into the ATA connector. The power cord is not required and is for use only when reading non-volatile memory.*



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Turn the ignition switch to the "ON" position, but **do not start** the engine. This will allow the EST to receive data from the electronic control components on the truck. If no data is received, press **"ENTER"** to retry. The information received will be data showing the current status of the engine.

To access the fault codes press the **"FUNC"** key to switch to the main menu.

NAVISTAR MRD
SELECT DESIRED
MENU
[ENGINE] ↔ PRO-LINK®

From the main menu select **"ENGINE"** by pressing the "←" key. This will cause the brackets to be placed around the **"ENGINE"** selection. Then press **"ENTER"**.

EST Tool Fault Codes (Cont.)

From the next menu select "**DIAGNOSTIC CODES"**. The selection will have the "↑ ↓" symbol on the screen. This means there are other selections available. By pressing the "↓" key the other selections will display on the screen. Press "↓" key until **"DIAGNOSTIC CODES"** appears on the screen.

NAVISTAR MRD ENGINE MENU		
↑	DIAGNOSTIC CODES	↓

Next press **"ENTER".** This causes the EST to enter the diagnostic codes section. From this point, diagnostic codes can be accessed.

The first option that will appear is **"ACTIVE CODES"**. By selecting this option, the fault codes that are currently occurring or that have occurred since the last key off cycle will be displayed.

NAVISTAR MRD DIAGNOSTIC CODES		
↑	ACTIVE CODES	↓

Press **"ENTER"**. If there are any "Active Codes", the first one will appear on the screen along with a description of the code. If there are any additional codes "Active" the "↑↓" symbol will appear on the screen. Press "↓" key to access additional codes. If there are not any codes "Active", **"NO ACTIVE CODES"** will appear on the screen.

To access "Inactive Codes" press the **"FUNC"** key. This will access the last prior menu selection. Then press the "↓" key to select **"INACTIVE CODES"**. Press the **"ENTER"** key.

NAVISTAR MRD DIAGNOSTIC CODES		
↑	INACTIVE CODES	↓

Inactive codes are faults that have occurred prior to the last key off cycle and are now stored in memory. An "Active Code" will become an "Inactive" code if the key is shut off.

Record all fault codes that are found. If there are any fault codes found, refer to Electronic Control System Diagnostics.

NOTE: *All current fault codes must be repaired and (cleared), before proceeding with further diagnostic testing.*

POSSIBLE CAUSES

Electronic Control Module (ECM) detectable faults which will cause a hard or no start condition are:

- Camshaft Position (CMP) sensor faults.
- Injection Pressure Regulator (IPR) output circuit check fault.
- Fuel Demand Command Signal (FDCS) and Cylinder Identification (CI) output circuit check faults.

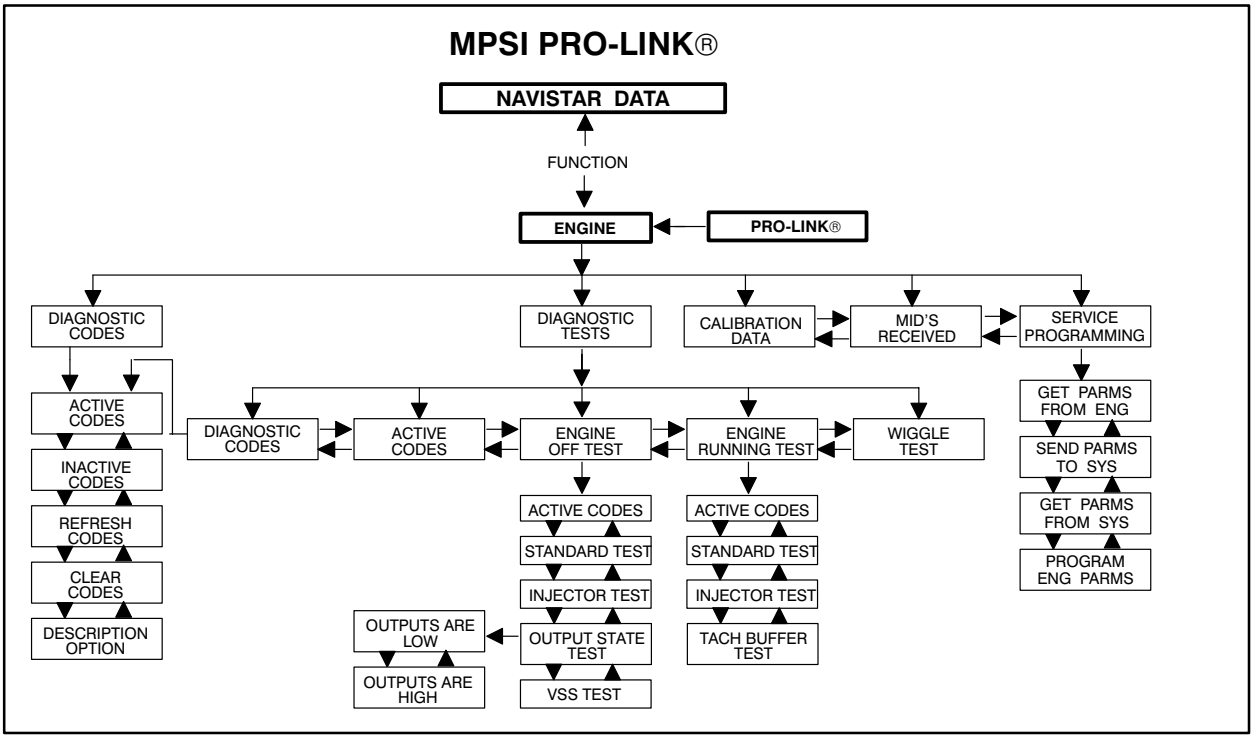
TOOLS REQUIRED

PRO-LINK® 9000 (ZTSE-43661).

SUPPLEMENTAL DIAGNOSTICS

If fault codes are set, refer to fault code diagnosis.

EST Tool Fault Codes (Cont.)



EST Tool - Engine Off Tests

EST TOOL - ENGINE OFF TESTS

● Select "Engine Off" test from diagnostic test menu

Faults Found	

□ Repair fault codes before continuing

PURPOSE

To determine if there are any electrical malfunctions that can be detected by the Electronic Control Module (ECM) during an on demand self test.

TEST PROCEDURE

NOTE: *Access "Diagnostic Codes" menu in EST and clear all fault codes before performing engine off tests.*

Access the **"ENGINE OFF TESTS"** in the **"DIAGNOSTIC TESTS"** section of the Electronic Service Tool (EST).

Press the **"FUNC"** key repeatedly, until the main menu appears on the screen.

NAVISTAR MRD
SELECT DESIRED
MENU
[ENGINE] ↔ PRO-LINK®

Move the brackets to engine selection by pressing the "←" key, then press **"ENTER"**

Next select the **"DIAGNOSTIC TESTS"** menu by pressing the "↓" key, until **"DIAGNOSTIC TESTS"** is shown on the screen. Press **"ENTER"** to make this selection.

NAVISTAR MRD
ENGINE MENU

↑ DIAGNOSTIC TESTS ↓

Press the "↓" key, until the **"ENGINE OFF TESTS"** is shown on the screen. At this point, press **"ENTER"**

NAVISTAR MRD
DIAGNOSTIC TESTS

↑ ENGINE OFF TESTS ↓

After the **"ENTER"** key is pressed, the EST will command the ECM to perform a [(OCC) Output Circuit Check] self test. During this test, the ECM will test the electrical continuity of the output circuits.

When the test is complete, the screen will display the number of faults found in the self test. If there are any additional faults found, press **"ENTER"** and the faults will be displayed. If there is more than one fault that was found during the test, the "↑↓" symbol will be shown on the screen. Press the "↓" key to access any additional faults.

NOTE: *If fault codes were not cleared before running engine off tests, all IDM faults and associated codes recorded during the test will be stored as "inactive" codes by the EST. to read the codes, access the "inactive" code menu.*

NOTE: *The program in the EST will only allow the engine off tests menu to be accessed once. To repeat engine off tests, select "standard test" to rerun the engine off tests.*

POSSIBLE CAUSES

- Defective electrical components or circuitry.
- Injection Pressure Regulator (IPR) output circuit check fault.
- Fuel Demand Command Signal (FDCS) and Cylinder Identification (CI) output circuit check faults.

TOOLS REQUIRED

PRO-LINK 9000 (ZTSE-43661).

SUPPLEMENTAL DIAGNOSTICS

If fault codes are set, refer to fault code diagnosis.

EST Tool - Injector Buzz Test

EST - INJECTOR "BUZZ TEST"

NOTE: "Engine Off Test" must be performed first, in order to gain access to the Injector "BUZZ TEST"

- Select "Injector Test" from "The Engine Off Tests" menu

Faults Found	

PURPOSE

To determine if the injectors are electronically functioning correctly, by energizing each injector in a programmed sequence. The Electronic Control Module (ECM) and Injector Drive Module (IDM) will monitor this test and transmit fault codes if any injector(s) or electrical circuitry are not functioning properly.

TEST PROCEDURE

NOTE: *Access "Diagnostic Codes" menu in EST and clear all fault codes.*

NOTE: *Engine off test must be performed first in order to access the injector "Buzz" test.*

After the **"Engine Off Test"** has been completed, press the "↓" key to access the **"INJECTOR TEST"**. If the tool is not on a menu screen, i.e. displaying of fault codes etc., press the **"FUNC"** key. This will access the **"DIAGNOSTIC TESTS"** menu. Press **"ENTER"** to begin the test.

NAVISTAR MRD
DIAGNOSTIC TESTS

↑ INJECTOR TEST ↓

During this test, the injector solenoids will produce an audible clicking sound when actuated. It is possible to detect a malfunctioning injector(s) by listening for the absence of the solenoid clicking sound.

NOTE: *If fault codes were cleared before the injector "Buzz" test, fault codes displayed will be actual faults found during the test. If codes were not cleared before testing, access "inactive" fault codes from diagnostic codes menu to retrieve faults found during this test.*

At the completion of the Injector Test, any faults that have been detected will be displayed. If there is more than one fault the "↑↓" symbol will be displayed. These additional faults can be accessed by pressing the "↓" key.

Record any faults found and refer to the Electronic Control System Diagnostics.

POSSIBLE CAUSES

- Bad wiring harness connection at injector solenoid.
- Open or shorted engine wiring harness to injector(s).
- Defective injector solenoid(s).
- Defective IDM.

TOOLS REQUIRED

PRO-LINK® 9000 (ZTSE-43661).

SUPPLEMENTAL DIAGNOSTICS

If fault codes are set, refer to fault code diagnosis.

STI Switch - Flash Codes

STI BUTTON - FLASH CODES

- Depress and hold "Engine Diagnostics" switch, then turn the ignition switch to the "ON" position.

Faults Found	

PURPOSE

To read faults detected by the Electronic Control Module (ECM), if the Electronic Service Tool (EST) is not available or the EST cannot receive "Self Test Input" data due to communications or component failures.

The Self Test Input (STI) switch is located at the instrument panel. Depressing the STI switch on the dash while turning the ignition switch to the "ON" position, will signal the ECM to start the Self Test Input diagnostics to check output circuits. If any faults are detected, the ECM will flash the "WARN ENGINE" light to indicate which faults have been detected.

NOTE: *Self test input diagnostics will not flash VPM Fault Codes.*

TEST PROCEDURE

Depress and hold the STI switch (located on vehicle dash). Turn the ignition switch to the "ON" position. **Do Not Start The Engine.** The ECM will begin to perform the self test to check the output circuits.

When the test is completed, the ECM will flash the red **"OIL/WATER"** light and amber **"WARN ENGINE"** light to signal the fault codes.

NOTE: *Fault codes can be accessed at anytime by turning the ignition switch to the "ON" position (do not start engine) and depressing the STI switch.*

To read the fault codes it will be necessary to count the number of times the **"ENGINE WARN"** light flashes. The following sequence of events occur each time the STI switch is depressed to obtain the fault codes:

1. The **"OIL/WATER"** light will flash one time to indicate the beginning of **Active** fault codes.
2. The **"WARN ENGINE"** light will flash repeatedly signaling the active fault codes.

NOTE: *All fault codes are three digits and code 111 indicates "No Faults" have been detected.*

3. Count the number of flashes in sequence. At the end of each digit of the code there will be a short pause. Three flashes and a pause would indicate the number 3. Therefore, two flashes, a pause, three flashes a pause, and two flashes a pause would indicate the code 232. If there is more than one fault code, the **"OIL/WATER"** light will flash once indicating the beginning of another active fault code.

After all the active codes have been flashed, the **"OIL/WATER"** light will flash twice to indicate the beginning of **INACTIVE** codes. Count the number of flashes from the **"WARN ENGINE"** light. If there is more than one inactive code, the **"OIL/WATER"** light will flash once in-between each fault code.

After all codes have been sent, the **"OIL/WATER"** light will flash three times indicating "END OF MESSAGE".

To repeat transmission of fault codes, depress the "ENGINE DIAGNOSTICS" switch which will signal the ECM to resend all stored fault codes.

If fault codes are set, refer to Electronic Diagnostic Form EGED-135-1 and fault code diagnosis.

POSSIBLE CAUSES

- Electronic component or circuitry failures.

TOOLS REQUIRED

None.

Fuel Pressure High Idle

FUEL PRESSURE HIGH IDLE

- Measure at regulator block.

Instrument	Spec.	Actual
0 - 160 PSI Gauge	30-65 PSI @ High idle	

☐ **If pressure is low, replace filter and retest.**

If pressure still low, perform "Transfer Pump Restriction Test".

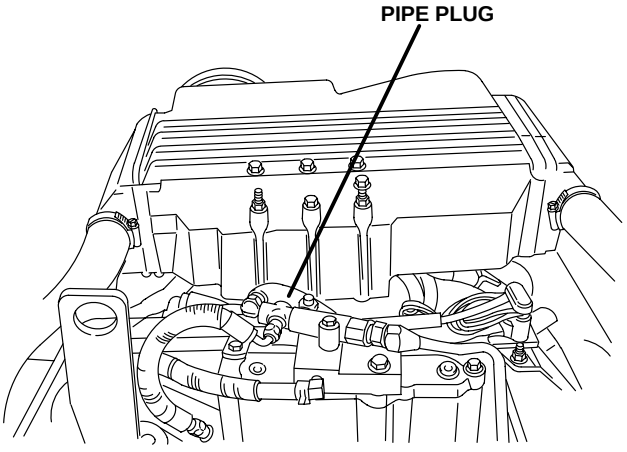
PURPOSE

To determine if fuel pressure is sufficient to correctly operate the engine.

TEST PROCEDURE

NOTE: *If fuel filter is equipped with a water-in-fuel probe, check with vehicle operator to determine if the water- in- fuel lamp has been illuminated during operation.*

1. Remove 1/8" pipe plug located on the fuel regulator block. Install 1/8 inch (3 mm) pipe fitting in place of the pipe plug.



76159

2. Connect a line from the fitting to the 0-160 PSI gauge of the Model D-200 Pressure Test Kit (ZTSE-2239). Start engine and run at low idle to check for fuel leaks in line to pressure gauge.

NOTE: *Bleed air from the fuel line to insure an accurate reading.*

3. Measure fuel pressure at high idle. **If pressure is not within specifications, replace fuel filter and re-check fuel pressure at high idle.**

NOTE: *It may take a number of crank cycles to purge the air out of the fuel system after replacing the fuel filter.*

If fuel pressure remains low after replacing the filter, perform Transfer Pump Restriction Test.

Fuel Pressure High Idle (Cont.)

POSSIBLE CAUSES

- A fuel filter could cause high restriction and low fuel pressure because of dirt or fuel jelling in cold ambient temperatures. Replace filter and retest.
- A kinked or severely bent fuel supply line or blockage at the pickup tube could cause restriction and therefore low fuel pressure.
- A loose fuel line on the suction side of the fuel system could cause air to be ingested into the system and cause low fuel pressure.
- The fuel pump could have internal damage, e.g. ruptured diaphragm, seized plunger or leaking check valves.

TOOLS REQUIRED

Model D-200 Pressure Test Kit (ZTSE-2239) (0 to 160 PSI fuel pressure gauge), appropriate line with 1/8” NPT fitting.

EST - Engine Running Test

EST-ENGINE RUNNING TEST

- Select “Engine Running” test from the diagnostic test menu.

NOTE: Engine will run rough during this test.

Faults Found	

☐ **Refer to Electronic Diagnostics (Sec. 5C) if fault code(s) set**

PURPOSE

To verify the engine’s electronic sensors and actuators are operating properly within their specified operating ranges. The Electronic Service Tool (EST) is used to signal the Electronic Control Module (ECM) to perform the “Engine Running Test”. The ECM will exercise the actuators and monitor sensor feedback signals. If a sensor or actuator problem exists, the ECM will transmit fault code(s) to the EST.

TEST PROCEDURE

1. Start and run engine until it reaches 160° F minimum.

NOTE: *Engine must be at least 160° F to allow the ECM to perform an accurate test of the engine sensors and actuators. If engine coolant temperature is below self test range, the EST tool will display an “ECT Out Of Self Test Range” message.*

2. Access the “Engine Running Test” from the **“DIAGNOSTIC TESTS”** menu by pressing the **“↓”** key, until **“ENGINE RUNNING TEST”** appears on the screen. Then press the **“ENTER”** key.

NAVISTAR MRD
DIAGNOSTIC TESTS

↑ ENGINE RUNNING TEST ↓

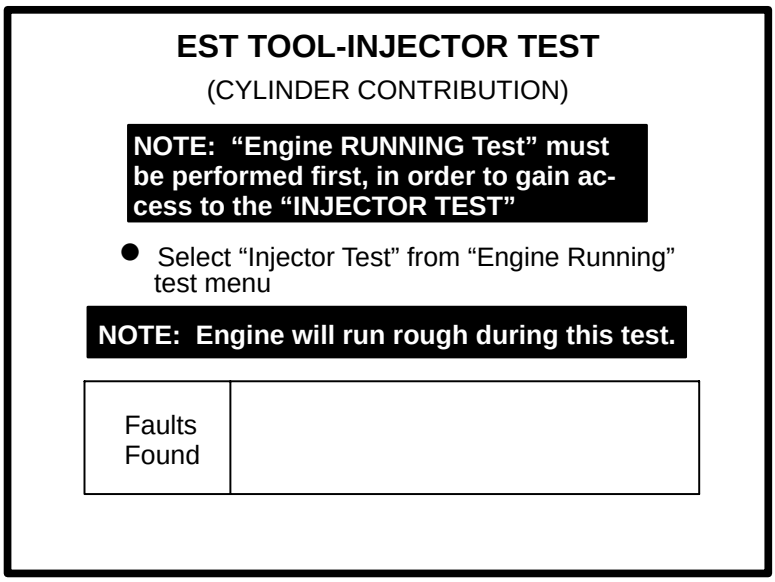
The ECM will then conduct the “Engine Running Test”. It will command the engine to accelerate to a pre-determined engine RPM and operate the Injection Pressure Regulator (IPR) valve.

The ECM will measure the effects of actuator movement via the sensors. At the completion of the test, the EST screen will display **“00 FAULTS”**, if no faults were detected. If EST indicates faults have been detected, press the **“ENTER”** key to display the fault codes.

POSSIBLE CAUSES

- Defective or inoperative sensors or actuators.
- Open or shorted wiring harness to sensors or actuators.
- Loose or corroded engine wiring harness connections at sensor or actuators.

EST Tool - Injector Test


EST TOOL-INJECTOR TEST
(CYLINDER CONTRIBUTION)
NOTE: "Engine RUNNING Test" must be performed first, in order to gain access to the "INJECTOR TEST"
Select "Injector Test" from "Engine Running" test menu
NOTE: Engine will run rough during this test.
Faults Found

PURPOSE

To verify that all power cylinders are contributing equally.

TEST PROCEDURE

NOTE: *The "Engine Running Test" must be performed first to access the injector test.*

After the **"Engine Running Test"** has been completed, press the "↓" key from the **"ENGINE RUNNING TEST"** screen to access the **"INJECTOR TEST"**. Then press the **"ENTER"** key.

DIAGNOSTIC TESTS
ENGINE RUNNING TESTS
↑ INJECTOR TEST ↓

NOTE: *The engine will run rough during the test.*

The Electronic Service Tool (EST) will signal the Electronic Control Module (ECM) to actuate each injector in a programmed sequence and then measure power cylinder performance.

At the completion of the test, the EST screen will display **"00 FAULTS"**, if no injector faults occurred. If EST indicates faults have been detected, press the **"ENTER"** key to display the fault codes. Record fault codes.

POSSIBLE CAUSES

- Broken compression rings, leaking or bent valves, bent push rods or connecting rods.
- Open or shorted engine wiring harness to injector(s).
- Defective injector solenoid(s)

TOOLS REQUIRED

PRO-LINK® 9000 (ZTSE-43661).

SUPPLEMENTAL DIAGNOSTICS

Refer to Electronic Control System Diagnostics.

Fuel Pressure - Full Load

FUEL PRESSURE - FULL LOAD

- Measure at regulator block.
- Measure at full load rated speed.

Instrument	Spec.	Actual
0-160 PSI Gauge	30-65 PSI @ Full load	

☐ **If pressure is low, replace fuel filter and retest.**

If pressure still low, perform transfer pump restriction test.

NOTE: FUEL PRESSURE (FULL LOAD) test is an "ON WATER TEST".

PURPOSE

To determine if fuel pressure is sufficient to correctly operate the engine at full load operating condition.

TEST PROCEDURE

NOTE: *Fuel pressure must be taken at full load. Fuel pressure may be sufficient at high idle, but may be unsatisfactory at full load operating conditions.*

1. Remove 1/8" pipe plug located on the fuel regulator block. Install 1/8 inch (3 mm) pipe fitting in place of the pipe plug.
2. Connect a line from the fitting to the 0-160 PSI gauge of the Model D-200 Pressure Test Kit (ZTSE-2239). Start engine and run at low idle to check for fuel leaks in line to pressure gauge.

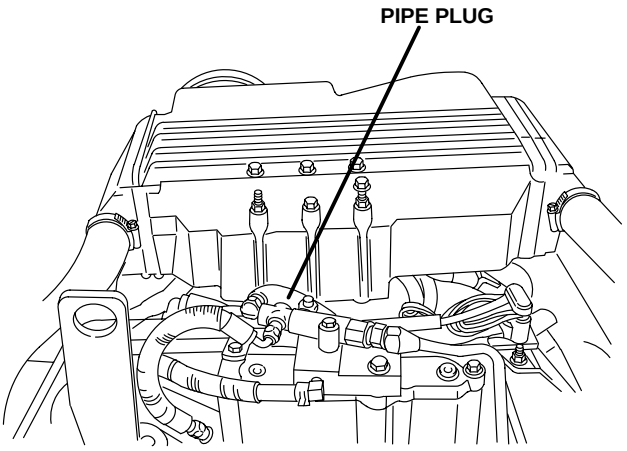
NOTE: *Bleed air from the fuel line to insure an accurate reading.*

3. Measure fuel pressure at full load. **If pressure is not within specifications, replace fuel filter and re-check fuel pressure.**

Fuel Pressure - Full Load (Cont.)

NOTE: *It may take a number of crank cycles to purge the air out of the fuel system after replacing the fuel filter.*

If fuel pressure remains low after replacing the filter, perform Transfer Pump Restriction Test.



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POSSIBLE CAUSES

- A fuel filter could cause high restriction and low fuel pressure because of dirt or fuel jelling in cold ambient temperatures. Replace filter and retest.
- A kinked or severely bent fuel supply line or blockage at the pickup tube could cause restriction and therefore low fuel pressure.
- A loose fuel line on the suction side of the fuel system could cause air to be ingested into the system and cause low fuel pressure.
- The fuel pump could have internal damage, e.g. ruptured diaphragm, seized plunger or leaking check valves.

TOOLS REQUIRED

Model D-200 Pressure Test Kit (ZTSE-2239) (0 to 160 PSI fuel pressure gauge), appropriate line with 1/8” NPT fitting.

Transfer Pump Restriction Test

TRANSFER PUMP RESTRICTION

- Measure at fuel pump inlet
- Measure at High idle

Instrument	Spec.	Actual
0-30” Hg. Vacuum Gauge	< 6” Hg.	

☐ If restriction is high, check for blockage between pump and fuel tank.

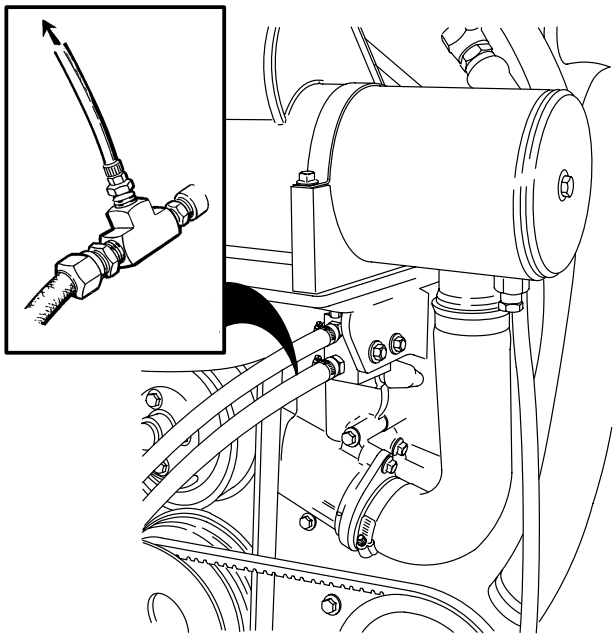
☐ If restriction is within spec., check for sticking regulator valve or debris.

PURPOSE

To determine if excessive restriction to fuel flow exists from the engine fuel inlet line to the fuel tank(s).

TEST PROCEDURE

1. Connect a tee between the fuel inlet line from tank and fuel supply line fitting. Connect a line from the tee to the 0-30” Hg. vacuum gauge of the D-200 Pressure Test Kit (ZTSE-2239).



76203

2. Measure fuel inlet restriction at high idle.
3. If restriction exceeds 6 in. Hg., locate the restriction on the suction side of the fuel system and correct.

NOTE: *If fuel inlet restriction is within specifications, refer to fuel regulator valve removal and inspection.*

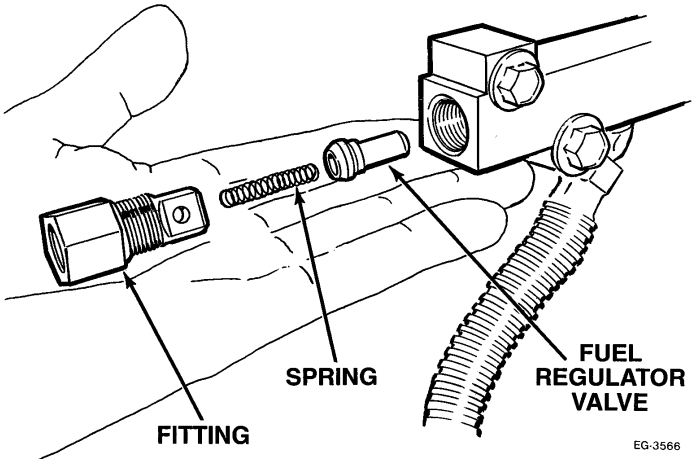
POSSIBLE CAUSES

- A fuel filter could cause high restriction and low fuel pressure because of dirt or fuel jelling in cold ambient temperatures. Replace filter and retest.
- A kinked or severely bent fuel supply line or blockage at the pickup tube could cause restriction and therefore low fuel pressure.
- A loose fuel line on the suction side of the fuel system could cause air to be ingested into the system and cause low fuel pressure.
- The fuel pump could have internal damage, e.g. ruptured diaphragm, seized plunger or leaking check valves.

TOOLS REQUIRED

Model D-200 Pressure Test Kit (ZTSE-2239) (0 to 30” Hg. vacuum gauge), “T” fitting, and appropriate fuel lines.

Fuel Regulator Valve



REMOVAL AND INSPECTION

1. Remove fuel return line from adapter fitting on fuel regulator block.
2. Use needle nose pliers to remove the fuel regulator spring and valve from the regulator.
3. Inspect fuel regulator valve seating surface for damage and insure spring is not broken.
4. Inspect inside of regulator block for dirt or debris that could restrict the flow of fuel past the regulator valve.

Injection Control Pressure Test

INJECTION CONTROL PRESSURE

(Oil Aeration-Poor idle quality)

NOTE: Test should be performed after engine has been run under load.

- Hold engine speed at high idle for 60 seconds.
- Monitor ICP pressure with EST data list or
- Measure at breakout box pins 27+ & 46– or Breakout "Tee" green and black -

Instrument	Spec.	Actual
EST	PSI	
DVOM (27+ , 46-)	Volts @ High Idle	

☐ **If ICP signal increases above 1040 PSI or 1.6 volts, change oil and retest.**

PURPOSE

To determine if engine lube oil is being aerated and causing poor idle quality.

TEST PROCEDURE

IMPORTANT: If engine oil is aerating, it may cause the engine to idle erratically. To determine if oil is being aerated, perform this test after engine has been run under a load.

NOTE: *Turn all accessories and the ignition off, before connecting est tool to ata diagnostic connector.*

1. Connect the Electronic Service Tool (EST) to the American Trucking Association (ATA) data link connector.
2. Start the engine and bring it to operating temperature.

NOTE: *Ensure the remote control is in neutral.*

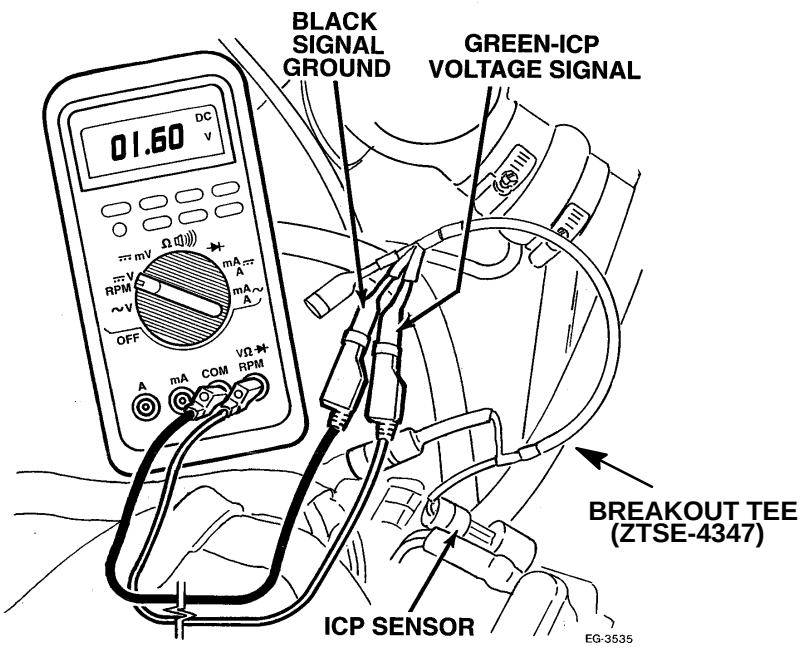
3. Press the "↓" key on the EST until **"INJ CNTL PSI"** appears on the screen.

BATT VOLTS	12.5
ENGINE RPM	0
INJ CNTL PSI	0
FUEL GAL/HR	0.3

4. Operate engine at high idle and monitor (ICP) Injection Control Pressure for 60 seconds on the EST.

Normal ICP pressure is 1000-1040 PSI. If ICP pressure does not stabilize below 1100 PSI and continues to rise while high idle speed is maintained, engine lube oil may be aerated. If this condition occurs, change oil and filter, then repeat ICP test.

Injection Control Pressure Test (Cont.)

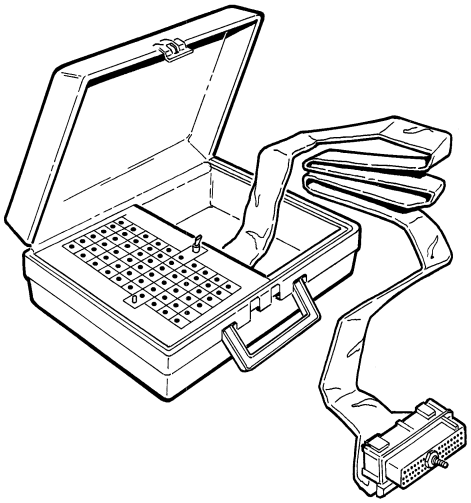


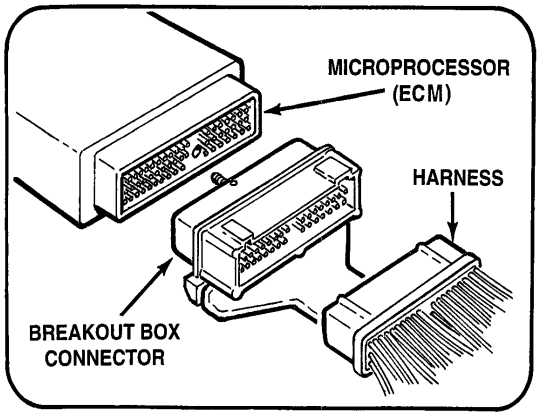
ALTERNATE METHOD OF MEASURING INJECTION CONTROL PRESSURE USING BREAKOUT "TEE"

1. Remove engine harness connector at ICP sensor.
2. Connect the breakout "TEE" to the removed engine harness connector and the ICP sensor.
3. Connect DVOM leads (+Green, -Black) to the breakout "TEE" as shown.
4. Start the engine and bring it to operating temperature.
5. Operate engine at high idle and monitor (ICP) voltage for 60 seconds. Normal ICP voltage is between 1.2 to 1.6 volts. If the ICP signal voltage continues to rise as high idle speed is maintained, the engine lube oil may be aerated. Change oil and filter, then repeat ICP test at high idle.

TOOLS REQUIRED

DVOM and breakout sensor "T" (ZTSE-4347).





ALTERNATE METHOD OF MEASURING INJECTION CONTROL PRESSURE USING BREAKOUT BOX

1. Connect breakout box at ECM.
2. Connect DVOM to breakout box terminal #s (+27, -46).
3. Start the engine and bring it to operating temperature.
4. Operate engine at high idle and monitor (ICP) voltage for 60 seconds. Normal ICP voltage is between 1.2 to 1.6 volts. If the ICP signal voltage continues to rise, as high idle speed is maintained, the engine lube oil may be aerated. Change oil and filter, then repeat ICP test at high idle.

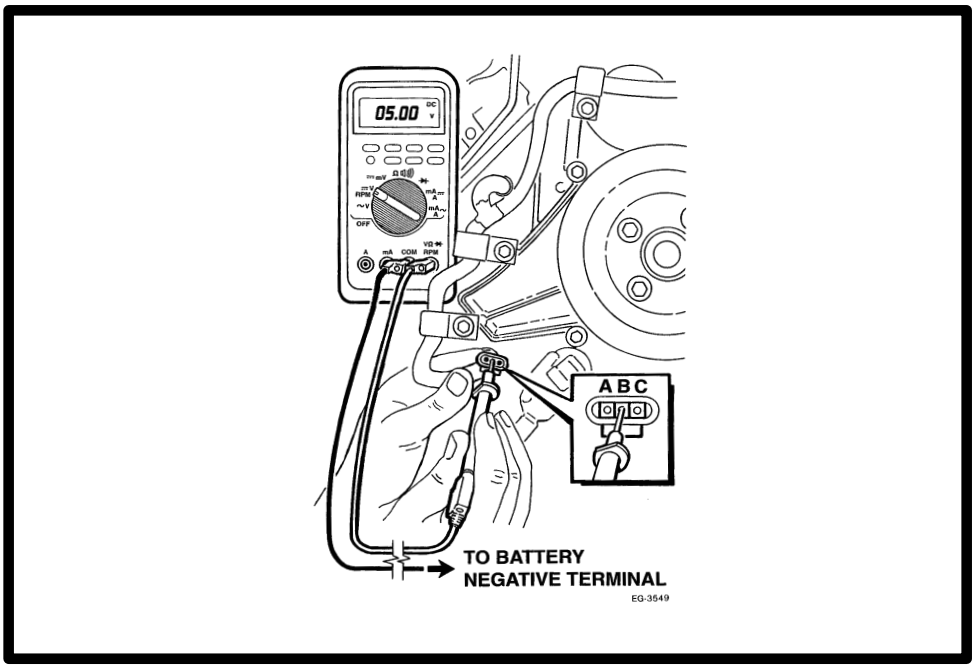
TOOLS REQUIRED

DVOM and breakout box (ZTSE-4346).

POSSIBLE CAUSES

- Extended oil drain intervals. The anti-foam additives in the oil may be depleted from severe use or extended oil drain intervals.

FUEL SYSTEM



5

C

ELECTRONIC CONTROL SYSTEM DIAGNOSTICS

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Flash Code Circuit Index

FAULT DESCRIPTION		
111	ECM	No Fault Detected - Flash code only
112	ECM PWR	Electrical System Voltage B+ out of range HIGH
113	ECM PWR	Electrical System Voltage B+ out of range LOW
114*	ECT	Engine Coolant Temperature Signal out of range LOW
115*	ECT	Engine Coolant Temperature Signal out of range HIGH
121*	MAP	Manifold Absolute Pressure Frequency Out of Range
122*	MAP	Manifold Absolute Pressure Signal is inactive
123	MAP	Man Absolute Press (MAP) above spec. level at low idle
124*	ICP	Injection Control Pressure Signal out of range LOW
125	ICP	Injection Control Pressure Signal out of range HIGH
131*	APS/IVS	Accelerator Position Signal out of range LOW
132*	APS/IVS	Accelerator Position Signal out of range HIGH
133*	APS/IVS	Accelerator Position Signal in-range fault
134*	APS/IVS	Accelerator Position and Idle Validation disagree
135*	APS/IVS	Idle Validation Switch circuit fault
141	N/A	
142	N/A	
143	CMP	Wrong number of CMP signal transitions per cam revolution
144	CMP	CMP Signal noise detected
145	CMP	CMP Signal inactive while ICP has increased
151	BARO	Barometric Pressure Signal out of range HIGH
152	BARO	Barometric Pressure Signal out of range LOW
154	IAT	Intake Air Temperature Signal out of range LOW
155	IAT	Intake Air Temperature Signal out of range HIGH
211*	EOP	Engine Oil Pressure Signal out of range LOW
212*	EOP	Engine Oil Pressure Signal out of range HIGH
213	SCCS	Remote Throttle Signal out of range LOW
214	SCCS	Remote Throttle Signal out of range HIGH
221	SCCS	SCCS Switch or Circuit fault
222	N/A	
223	DCL/ATA	VPM not communicating with ECM

* - Indicates WARN ENGINE LAMP on when fault is set.

Flash Code Circuit Index

FAULT DESCRIPTION		
224	KAM PWR	KAM Corrupt
231	DCL/ATA	ATA Common Fault
232	DCL/ATA	Unable to forward ECM message to ATA DCL
233	TACH	Tachometer buffer is inactive
234	DCL/ATA	Unable to forward ATA message to ECM
235	DCL/ATA	VPM/ECM DCL fault
241	IPR	Injection Control Pres. Regulator OCC Self Test failed
242	ECM/IDM	FDCS circuit to IDM OCC Self Test failed
243	IDM PWR	IDM Power Relay OCC Self Test failed
244	N/A	
245	EPR	Exhaust Pressure Regulator OCC Self Test failed
251	GPC	Glow Plug Controller OCC Self Test failed
252	GPC	Glow Plug Lamp OCC Self Test failed
253	ECM/IDM	Fuel Inj. Sync Circuit OCC Self Test failed
254	ECM	OCC Self Test ECM test circuit out of range HIGH
255	ECM	OCC Self Test ECM test circuit out of range LOW
311*	EOT	Engine Oil Temperature Signal out of range LOW
312*	EOT	Engine Oil Temperature Signal out of range HIGH
315*		Engine Speed (Tach RPM) limit exceeded
316	ECT	Engine Coolant Temperature Unable to Reach commanded set point
321	ECT**	Engine Coolant Temperature above warning level
322	ECT**	Engine Coolant Temperature above critical level
323	ECL	Engine Coolant Level below warning/critical level
324		Idle Shutdown Timer Enabled Engine Shutdown
325	ECT	Power reduced, matched to cooling system performance
331*	IPR	Injection Control Pressure above system working range
332*	ICP	Injection Control Pressure above spec. with engine off
333*	IPR	Injection Control Pressure above/below desired level

* - Indicates WARN ENGINE LAMP on when fault is set.

** - Faults only available if Engine Protection is enabled.

Flash Code Circuit Index

FAULT DESCRIPTION		
334*	IPR	ICP unable to achieve setpoint (poor performance)
335*	IPR	ICP unable to build pressure during cranking
421	INJ	LOW to HIGH Side Open - Cyl 1
422	INJ	LOW to HIGH Side Open - Cyl 2
423	INJ	LOW to HIGH Side Open - Cyl 3
424	INJ	LOW to HIGH Side Open - Cyl 4
425	INJ	LOW to HIGH Side Open - Cyl 5
426	INJ	LOW to HIGH Side Open - Cyl 6
427	INJ	LOW to HIGH Side Open - Cyl 7
428	INJ	LOW to HIGH Side Open - Cyl 8
431	INJ	LOW to HIGH Side Short - Cyl 1
432	INJ	LOW to HIGH Side Short - Cyl 2
433	INJ	LOW to HIGH Side Short - Cyl 3
434	INJ	LOW to HIGH Side Short - Cyl 4
435	INJ	LOW to HIGH Side Short - Cyl 5
436	INJ	LOW to HIGH Side Short - Cyl 6
437	INJ	LOW to HIGH Side Short - Cyl 7
438	INJ	LOW to HIGH Side Short - Cyl 8
441	INJ	LOW side short to VBAT- Cyl 1
442	INJ	LOW side short to VBAT - Cyl 2
443	INJ	LOW side short to VBAT - Cyl 3
444	INJ	LOW side short to VBAT - Cyl 4
445	INJ	LOW side short to VBAT - Cyl 5
446	INJ	LOW side short to VBAT - Cyl 6
447	INJ	LOW side short to VBAT - Cyl 7
448	INJ	LOW side short to VBAT - Cyl 8

* - Indicates WARN ENGINE LAMP on when fault is set.

Flash Code Circuit Index

FAULT DESCRIPTION		
452	INJ	LOW side short to ground - Cyl 2
453	INJ	LOW side short to ground - Cyl 3
454	INJ	LOW side short to ground - Cyl 4
455	INJ	LOW side short to ground - Cyl 5
456	INJ	LOW side short to ground - Cyl 6
457	INJ	LOW side short to ground - Cyl 7
458	INJ	LOW side short to ground - Cyl 8
461	Perf. Diag.	Cyl. Contribution Test Failure - Cyl 1
462	Perf. Diag.	Cyl. Contribution Test Failure - Cyl 2
463	Perf. Diag.	Cyl. Contribution Test Failure - Cyl 3
464	Perf. Diag.	Cyl. Contribution Test Failure - Cyl 4
465	Perf. Diag.	Cyl. Contribution Test Failure - Cyl 5
466	Perf. Diag.	Cyl. Contribution Test Failure - Cyl 6
467	Perf. Diag.	Cyl. Contribution Test Failure - Cyl 7
468	Perf. Diag.	Cyl. Contribution Test Failure - Cyl 8
511*	INJ	Bank 1 has multiple faults
512*	INJ	Bank 2 has multiple faults
513*	INJ	High Side to Bank 1 Open
514*	INJ	High Side to Bank 2 Open
515*	INJ	Bank 1 High Side Short to Ground or VBAT
521*	INJ	Bank 2 High Side Short to Ground or VBAT
522*	IDM PWR	IDM Internal Failure
523	IDM PWR	IDM power voltage is LOW
524*	INJ	Both High Side Switches shorted together
531*	ECM/IDM	Cylinder Identification (CI) Signal Low
532*	ECM/IDM	Cylinder Identification (CI) Signal high
541*	ECM/IDM	IDM Feedback TOGGLE not detected by ECM
543*	ECM/IDM	IDM faults not received
544	INJ	Injector Fault in Bank 2
545	INJ	Injector Fault in Bank 1
612*	CMP	Incorrect ECM installed for CMP (timing) wheel

* - Indicates WARN ENGINE LAMP on when fault is set.

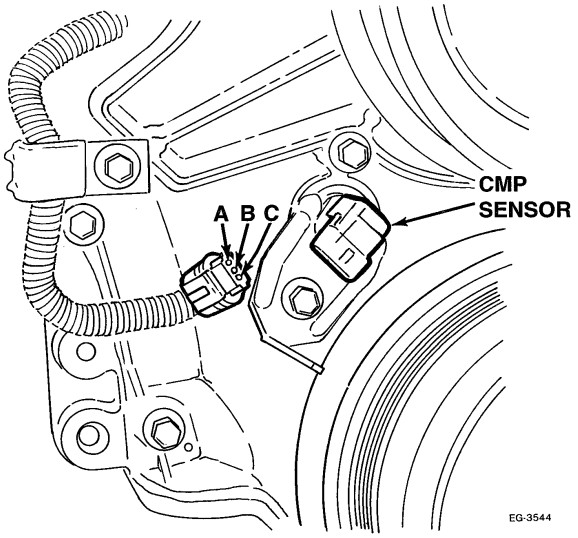
Flash Code Circuit Index

FAULT DESCRIPTION		
613*	VPM	Installed ECM not compatible with VPM Software
614*	VPM	Installed VPM not compatible with ECM software
615	ECM	Programmable Parameter KAM Corrupt fault
621*	VPM	Engine using MFG. Default rating program engine
622*	VPM	Engine using Field Default rating
623*	VPM	Invalid Engine Rating Code; Check VPM programming
625	ECM	Module Software Background Process was inactive
631	ECM	ROM (Read Only Memory) Self Test fault
632	ECM	RAM Memory-CPU Self Test Fault
633	DCL/ATA	VPM is communicating incorrectly with ECM
634	VPM	Internal Fuelmeter memory location in error
635	VPM	Internal Hourmeter memory location in error
641	VPM	Internal Odometer memory location in error
642	VPM	Internal Fuelmeter Fault
643	VPM	Internal Hourmeter Fault
644	VPM	Internal Odometer Fault
645	VPM	Internal EEPROM memory location error
651	VPM	Feature memory data content corrupted
652	VPM	Engine/Fuel memory data content corrupted
653	VPM	Engine/Rating memory data content corrupted
654	VPM	Watchdog Timeout

Diagnostic Procedures

Inspection

The basic diagnostic procedure recommended for most sensor and actuator circuits is to disconnect the harness at the connector and inspect for corrosion, bent pins, spread pins or any condition that could cause a loose or intermittent connection.



Connector Checks To Ground (-)

The second step is to measure the resistance of all wiring harness connectors to ground (preferably the negative battery cable) to determine if a short to ground condition is present. **It is important that during this test all accessories be turned off, current flow in the system will affect resistance readings. If the reading is fluctuating greatly, disconnect the battery and measure to the negative battery cable.**

- Signal ground (marked “A” on all engine sensor harness connectors should measure less than 5 ohms. (Signal ground on sensor connectors vary).
- The V Ref and signal lines, with the processor connected, will normally measure greater than 1000 ohms.

NOTE: *The symbols < & > are used on each diagnostic circuit page. They are defined as follows:*

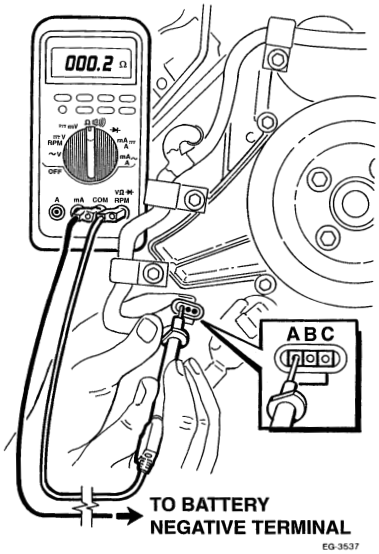
(<) Indicates a value less than

(>) Indicates a value greater than

Example: < 5 ohms = less than 5 ohms

Example: > 5 ohms = more than 5 ohms

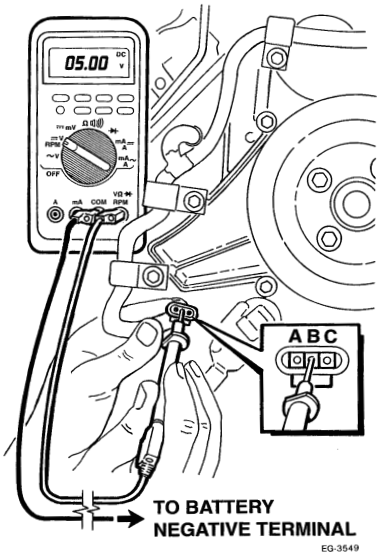
- Power ground on an actuator circuit should measure less than 5 ohms. The control side of an actuator circuit will normally measure greater than 1000 ohms.



Connector Voltage Checks

Turn the ignition key to the “ON” position and measure if the expected voltages are present at the connector. On circuits with expected voltages, this test will verify the integrity of that circuit. On circuits without an expected voltage, this test will determine if that circuit is shorted or mis-wired to a voltage source.

- Signal ground (marked “A” on all engine sensor harness connectors should measure less than .25 volts.)
- V Ref should measure 5.00 volts ± .50 volts. If this is higher or lower than expected, disconnect sensors one at a time to determine if a sensor is biasing the circuit and refer to V Ref procedures.



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- Sensor signal lines will measure 0 to .25 volts if the circuit is designed to “pull down” when disconnected, or a higher voltage (normally 4.6 to 5, or 12 volts) if it is designed as a “pull up circuit”. A “pull up” signal circuit that measures the expected value normally indicates a good circuit.
- Actuator circuits may be either on/off type circuits (normally 12 volts) or pulse width modulated circuits (12 volts controlled by a % duty cycle).
- Communication circuits between the Electronic Control Module (ECM) and the Injector Driver Module (IDM) are designed to either “pull up” or “pull down”. That means that one end of the communication circuit is normally at a high or 12 volt level and the signal is created by the low side toggling or switching the high side to ground. Communication lines are best diagnosed with the breakout box installed and measuring the expected voltage with the key in the “ON” position and the engine off.

Harness Resistance Checks

Harness resistance tests are performed when a circuit is suspected of having high resistance or being open. These tests are performed with the breakout box connected and by measuring resistance from the sensor connector end to the processor connector. If an open circuit or high resistance is encountered, the problem is most easily isolated by separating the circuit at the interim connectors (normally the Deutsch connector on the valve cover or the cowl) and measuring resistance through both halves of the circuit.

Operational Signal Checks

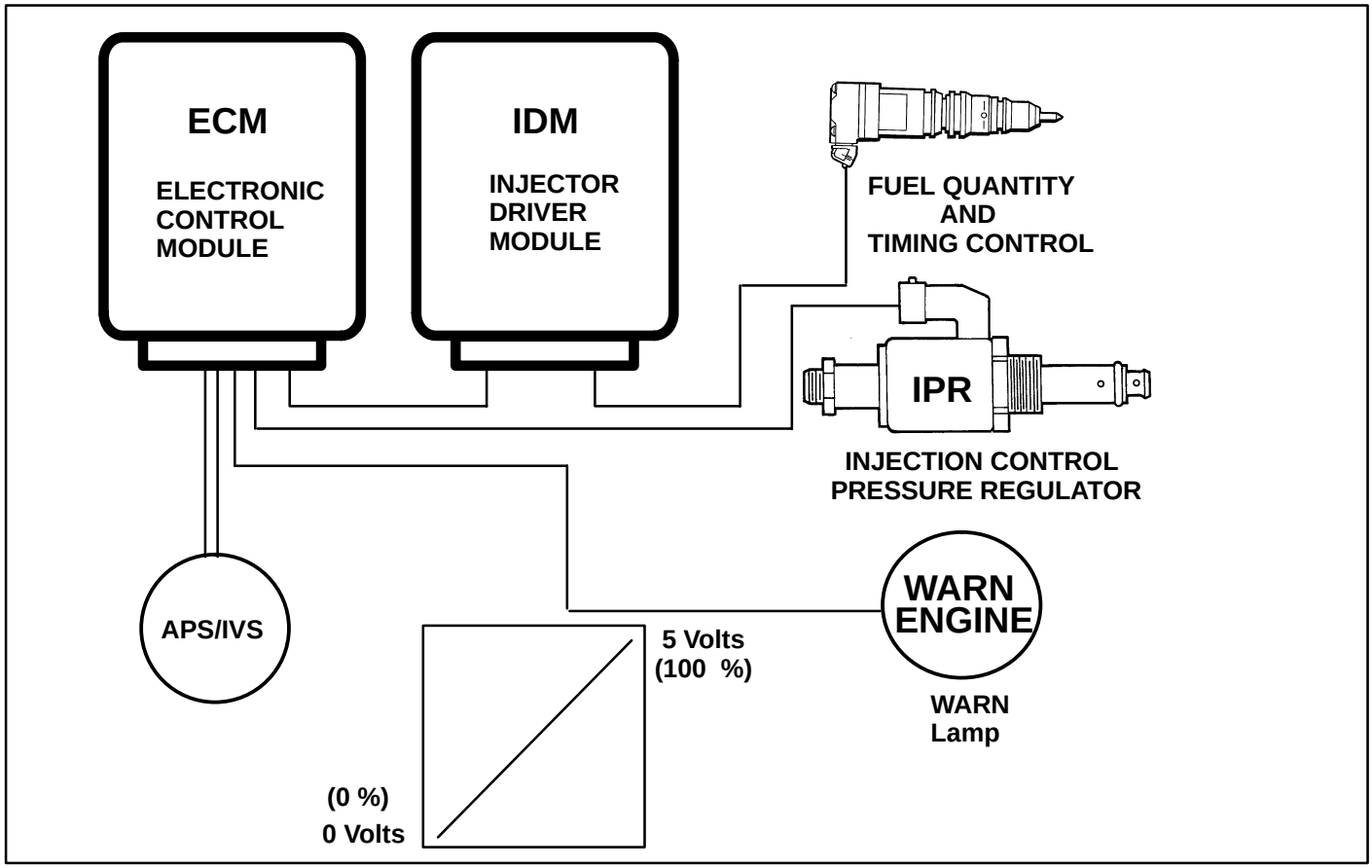
These checks are made with the breakout box installed and are normally measuring a signal voltage or frequency. They are useful for determining an in range type fault or an intermittent connection.

In the case of an intermittent fault, monitoring a suspected circuit and recreating the environmental or physical conditions that caused the complaint will help verify if a problem is in a particular circuit.

It is critical when measuring the signal level of a circuit to understand it’s function and whether it is a analog voltage, digital frequency, sine wave or digital communication signal. A standard Digital Volt Ohm Meter (DVOM) has certain limitations in measuring any circuit that has a frequency.

Circuit Function and Diagnostics

APS/IVS - Accelerator Position Sensor



SIGNAL FUNCTIONS

The Accelerator Position Sensor (APS) is a potentiometer type sensor which, when supplied with a 5 volt reference signal from the Electronic Control Module (ECM), provides a linear analog voltage signal that indicates the driver's demand for power.

The Idle Validation Switch (IVS) is a 0/12 volt switch that provides the ECM with a redundant signal to verify when the lever is in the idle position.

Fuel Quantity and Timing Control - The APS signal is used in calculating desired fuel quantity and injector timing.

Injection Control Pressure - Accelerator position is one of the controlling variables in the calculation of desired injection control pressure.

FAULT DETECTION/MANAGEMENT

Any detected malfunction of the APS or IVS sensor circuit will illuminate the WARN ENGINE lamp.

An APS signal that is detected out of range high or low by the ECM will cause the engine to ignore the APS signal and will only allow the engine to operate at low idle.

If a disagreement in the state of IVS and APS is detected by the ECM and the ECM determines that it is an IVS fault, the ECM will only allow a maximum of 50% APS to be commanded.

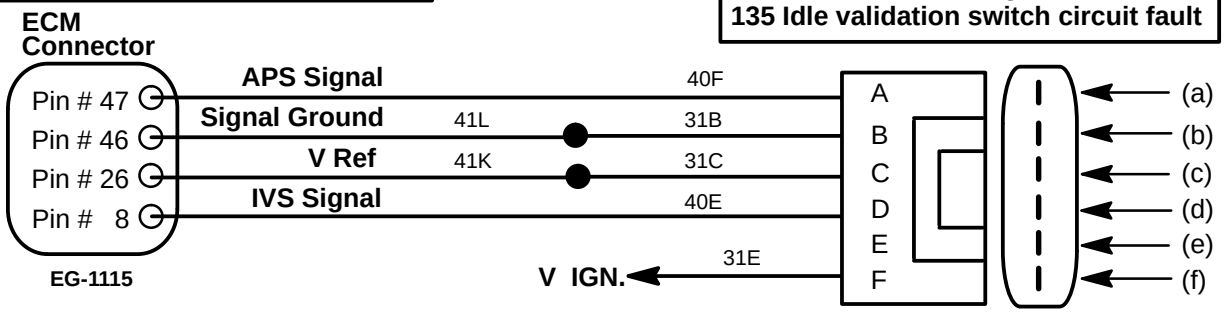
If a disagreement in the state of IVS and APS is detected by the ECM and the ECM can not discern if it is an APS or IVS fault, or if it is an APS fault, the engine will be allowed to operate at low idle only.

APS/IVS - Accellerator Position Sensor (Cont.)

Accelerator Position Sensor & Idle Validation Switch (APS/IVS)

APS/IVS

Fault Codes:
131 APS signal out of range low
132 APS signal out of range high
133 APS signal in-range fault
134 APS and IVS disagree
135 Idle validation switch circuit fault



After removing connectors always check for damaged pins, corrosion, loose terminals etc.

Connector Checks to Ground
(Check with Sensor Connector Disconnected and Ignition key off, all accessories off)

Test Points	Spec.	Comments
A to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.
B to Grd.	< 5 ohms	Resistance to ground, check with key off, > than 5 ohms harness is open.
C to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.
D to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.

Connector Signal Checks (Check with Sensor Connector Disconnected and Ignition Key On)

Test Points	Spec.	Comments
A to Grd.	0 - .25 volts	If greater than .25 volts signal ground wire is shorted to V Ref or battery.
B to Grd.	0 - .25 volts	Signal ground no voltage expected.
C to Grd.	5 ± .5 volts	VRef check key on, if VRef not present check open/short to grd #26 to C, see VRef circuit.
D to Grd.	0 - .25 volts	If greater than .25 volts signal ground wire is shorted to V Ref or battery.
F to Grd.	12 ± 1.5 volts	< 10.5 v check for poor connection, 0 v check for open/short to grd circuit or blown fuse.

Harness Resistance Checks (Check with breakout box installed on engine harness only)

Test Points	Spec.	Comments
#47 to A	< 5 ohms	Resistance from 60 pin connector to harness connector - APS Signal
#46 to B	< 5 ohms	Resistance from 60 pin connector to harness connector - Signal Ground
#26 to C	< 5 ohms	Resistance from 60 pin connector to harness connector - V Ref
#8 to D	< 5 ohms	Resistance from 60 pin connector to harness connector - IVS Signal
V IGN. to F	< 5 ohms	Resistance from V IGN. power to harness connector

Operational Voltage Checks
(Check with breakout box and the EST tool installed key "ON")

	APS Test Points (+) #47 to (-) #46		IVS Test Points (+) #8 to (-) #46		
Position	Voltage	% APS	Voltage	% APS	Comments
Low Idle	.25 to .8 V	0 %	0 volts	0 %	IVS voltage should toggle just off low idle position.
High Idle	3 to 4.5 V	98-100%	12 ± 1.5 v	98-100%	If APS measures only 50% and volt signal in spec., IVS fault detected.

Fault Code Descriptions

131 APS signal was less than 0.146 volts for more than 0.5 seconds *****
132 APS signal was greater than 4.56 volts for more than 0.5 second *****
133 APS signal in-range fault *****
134 APS and IVS agree *****
135 Idle validation switch circuit fault - 50% APS only.

*** - IF FAULT CODE IS SET, ENGINE OPERATION WILL DEFAULT TO RUN AT LOW IDLE SPEED ONLY.**

APS/IVS - Accelerator Position Sensor (Cont.)

APS/IVS EXTENDED SYSTEM DESCRIPTION

The D7.3L engine uses an electronic accelerator assembly that includes an Accelerator Position Sensor (APS) and Idle Validation Switch (IVS). These two functions are integrated into one component mounted on the engine.

The engine Electronic Control Module (ECM) determines the position of the accelerator by processing the input signals from the Accelerator Position Sensor (APS) and Idle Validation Switch (IVS).

ACCELERATOR POSITION SENSOR (APS)

Refer to circuit diagram for the following discussion.

The ECM sends a regulated 5 volt signal through ECM connector terminal 26 to APS connector terminal C. The APS then returns a variable voltage signal (depending on throttle position) from APS connector terminal A to the ECM at terminal 47. The APS is grounded from connector terminal B to the ECM signal ground terminal 46.

APS AUTO-CALIBRATION

The ECM learns the lowest and highest positions by reading and storing the minimum and maximum voltage levels from the APS. In this manner the ECM "auto-calibrates" the system to allow maximum sensitivity. The ECM auto-calibrates as the key is ON, but when the key is turned OFF, these values are lost. When the key is turned on again, this process starts over. When the throttle cable is disconnected (or new one installed), it does not need to be calibrated, as the calibration happens when the key is turned on.

IDLE VALIDATION SWITCH (IVS)

The ECM expects to receive one of two signals through ECM connector terminal 8 from APS/IVS connector terminal D:

- 0 volts when the throttle is at the idle position.
- 12 volts when the throttle is advanced.

The Idle Validation Switch receives 12 volt ignition voltage from 10A fuse. When the throttle lever is NOT in the idle position (throttle applied), the IVS sends a 12 volt signal to the ECM.

The ECM compares the inputs it receives at terminals 47 and 8 from the APS/IVS to verify when the throttle lever is in the idle position. If the APS signal at terminal 47 indicates throttle is being applied, then the ECM expects to see 12 volts at IVS terminal 8. If the APS signal at terminal 47 indicates throttle is not applied, then the ECM expects to see 0 volts at the IVS terminal 8. The timing process is critical between the APS and the IVS sensors. For this reason, it is very difficult to determine if the APS/IVS assembly is working properly using a volt-ohmmeter.

ECM DIAGNOSTICS

When the key is ON, the ECM continuously monitors the APS/IVS circuits for expected voltages. It also compares the APS and IVS signals for conflict. If the signals are not what the ECM expects to see, Fault codes will be set.

Flash Code *131*

ATA Code PID 91 FMI 4 -

ECM: *APS Out of Range Low*

The ORL (out of range low) code 131 is set if the ECM detects a voltage lower than 0.146 volts at terminal 47. Possible causes include: a short to ground or an open in circuit 40F. This code is displayed by either the Pro-link® EST or using the Engine Warn Light to flash codes.

When code 131 is active, the ECM restricts engine speed to idle and turns the Engine Warning Light ON. If the condition causing code 131 is intermittent and the condition is no longer present, the code will become inactive and normal engine operation will resume. If code 131 is active, perform Testing APS Circuits.

Flash Code *132*

ATA Code PID 91 FMI 3 -

ECM: *APS Out Of Range High*

The ORH (out of range high) code 132 is set if the ECM detects a voltage greater than 4.56 volts at terminal 47. Possible cause: short to VREF or 12 volts in circuit 40F. This code is displayed by either the Pro-link® EST or using the Engine Warn Light to flash codes.

APS/IVS - Accelerator Position Sensor (Cont.)

Flash Code *132*

ATA Code PID 91 FMI 3 -

ECM: *APS Out Of Range High* (Continued)

When code 132 is active, the ECM restricts engine speed to idle and turns the Engine Warn Light ON. If the condition causing code 132 is intermittent and the condition is no longer present, the code will become inactive and normal engine operation will resume. If code 132 is active, perform Testing APS Circuits.

Flash Codes *133, 134 And 135*

APS IN-RANGE Faults

The ECM checks the voltage output of the APS by comparing the APS signal with the IVS signal. APS and IVS signals can disagree in two cases:

- The APS signal indicates the pedal is pressed down to accelerate, but the IVS signal indicates idle position.
- The APS signal indicates the pedal has been released to allow the engine to return to idle, but the IVS signal indicates off-idle position of the pedal.

If the ECM detects either of the above conditions, the ECM attempts to isolate the source of conflict. If code(s) 133, 134 and/or 135 are active, perform Testing IVS Circuits and Testing APS Circuits.

Flash Code *133*

ATA Code PID 91 FMI 2 -

ECM: *APS In Range Fault*

If the IVS signal is changing and the APS signal is constant, the ECM assumes APS is the conflict source and sets code 133. Engine rpm is restricted to idle and the Engine Warn Light is turned ON.

Flash Code *134*

ATA Code PID 91 FMI 7—

ECM: *APS/IVS Disagree*

If neither the APS or IVS is changing, or both are changing or the ECM cannot determine the faulty code in specified time, then code 134 is set, engine rpm is restricted to idle and the Engine Warn Light is turned ON.

Flash Code *135*

ATA Code SID 230 FMI 11-

ECM: *IVS Circuit Fault*

If the APS is changing and IVS is constant, the ECM assumes IVS is the conflict source and sets flash code 135. In this case the ECM limits the APS signal to a lower value, which provides less than full rpm, but does not limit engine rpm to idle. The Engine Warn Light is not turned ON.

Note that codes 133, 134 and 135 are caused by an intermittent condition, the codes remain ACTIVE until the vehicle has been shutdown and restarted. They do not recover without cycling the key switch.

TROUBLESHOOTING

The APS and IVS circuits operate with low current levels. When troubleshooting, pay special attention to the connectors.

BEFORE PERFORMING ANY TEST

Inspect connectors for pushed back, damaged, corroded or dirty terminals, as well as making sure that the terminals and wires are properly crimped. Make sure the connectors are properly joined together. Also check for any damage to the wiring and make sure system grounds are clean and tight.

TESTING APS/IVS CIRCUITS

- If flash codes 131 or 132 are present, perform Testing APS Circuits. If flash codes 133, 134 or 135 are present, perform Testing IVS Switch & Circuits.

These tests systematically check the APS and IVS circuits for:

A. Short circuits to ground.

B. Short circuits to unwanted voltage sources.

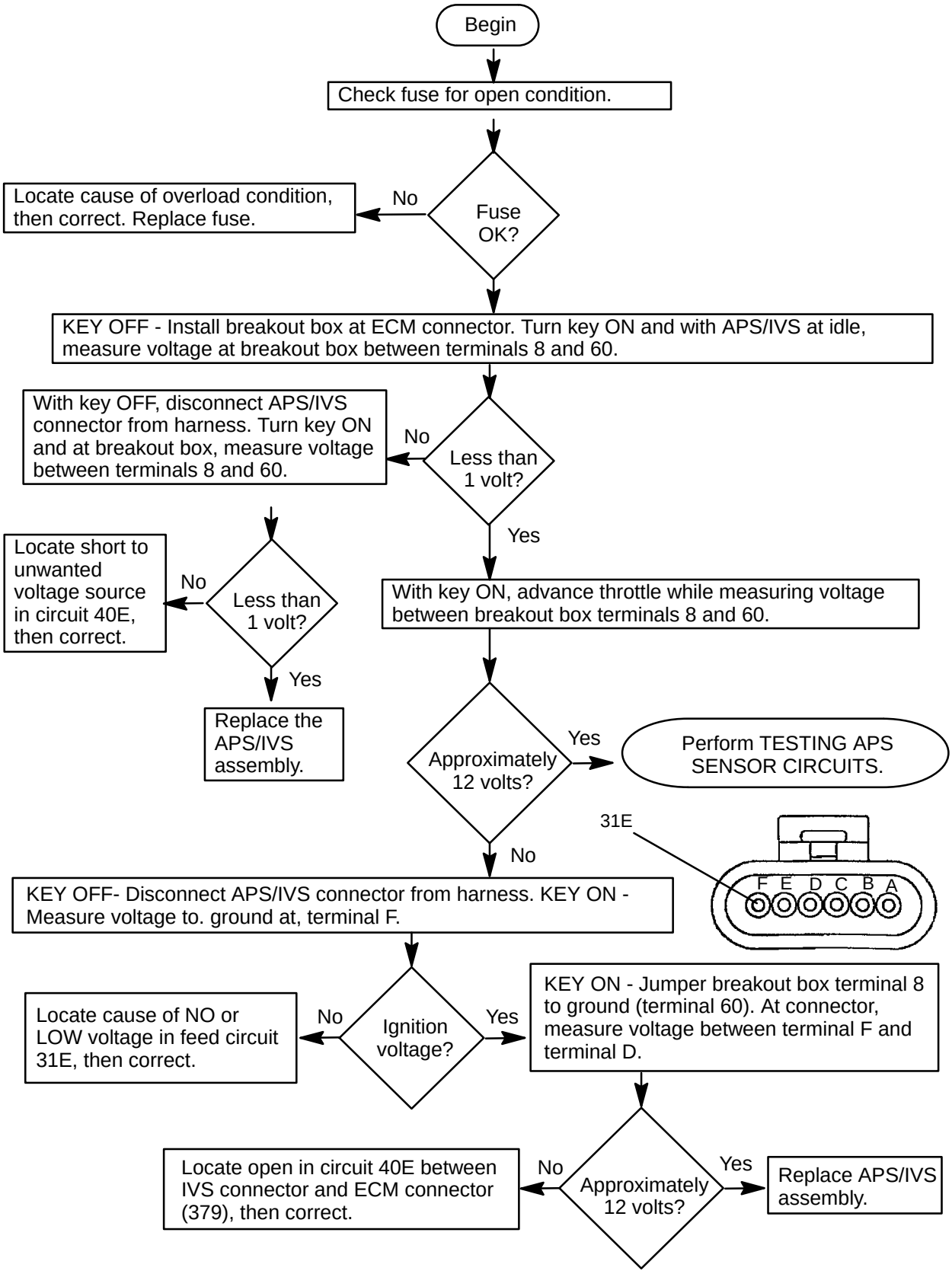
C. Open circuits or excessive circuit resistance.

D. Proper feeds and grounds.

NOTE: *The tests performed on the accelerator assembly check for shorts, opens and correct resistance values, but do not check for proper timing between the two functions. If all of the circuits between the ECM and the accelerator assembly check good, then the APS/IVS accelerator switch should be replaced.*

APS/IVS - Accelerator Position Sensor (Cont.)

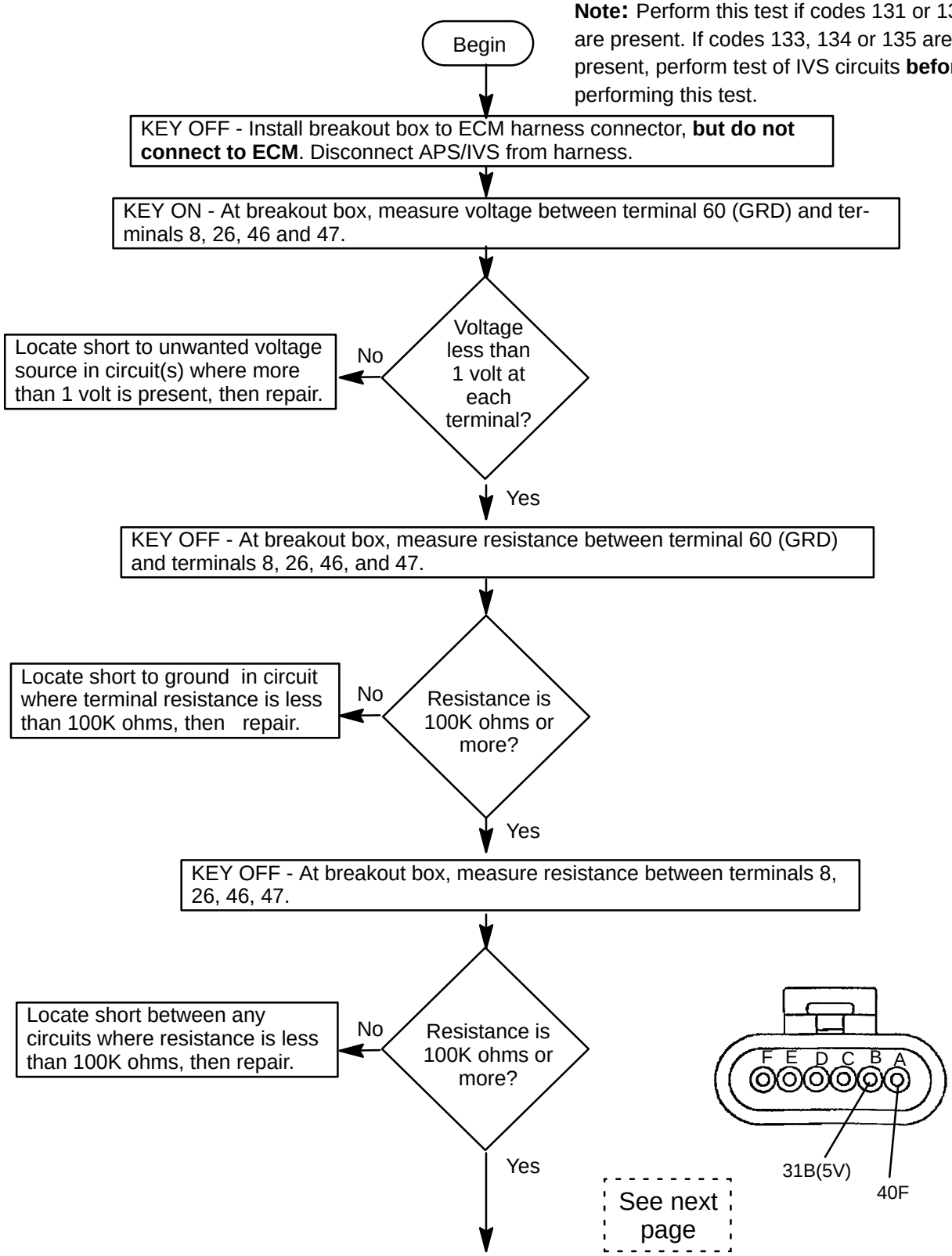
TESTING (IVS) IDLE VALIDATION SWITCH AND CIRCUITS


Begin
Check fuse for open condition.
Fuse OK?
No
Locate cause of overload condition, then correct. Replace fuse.
KEY OFF - Install breakout box at ECM connector. Turn key ON and with APS/IVS at idle, measure voltage at breakout box between terminals 8 and 60.
Less than 1 volt?
No
With key OFF, disconnect APS/IVS connector from harness. Turn key ON and at breakout box, measure voltage between terminals 8 and 60.
Yes
With key ON, advance throttle while measuring voltage between breakout box terminals 8 and 60.
Less than 1 volt?
No
Locate short to unwanted voltage source in circuit 40E, then correct.
Yes
Replace the APS/IVS assembly.
Approximately 12 volts?
Yes
Perform TESTING APS SENSOR CIRCUITS.
No
31E
F E D C B A
KEY OFF- Disconnect APS/IVS connector from harness. KEY ON - Measure voltage to. ground at, terminal F.
Ignition voltage?
No
Locate cause of NO or LOW voltage in feed circuit 31E, then correct.
Yes
KEY ON - Jumper breakout box terminal 8 to ground (terminal 60). At connector, measure voltage between terminal F and terminal D.
Approximately 12 volts?
No
Locate open in circuit 40E between IVS connector and ECM connector (379), then correct.
Yes
Replace APS/IVS assembly.

APS/IVS - Accelerator Position Sensor (Cont.)

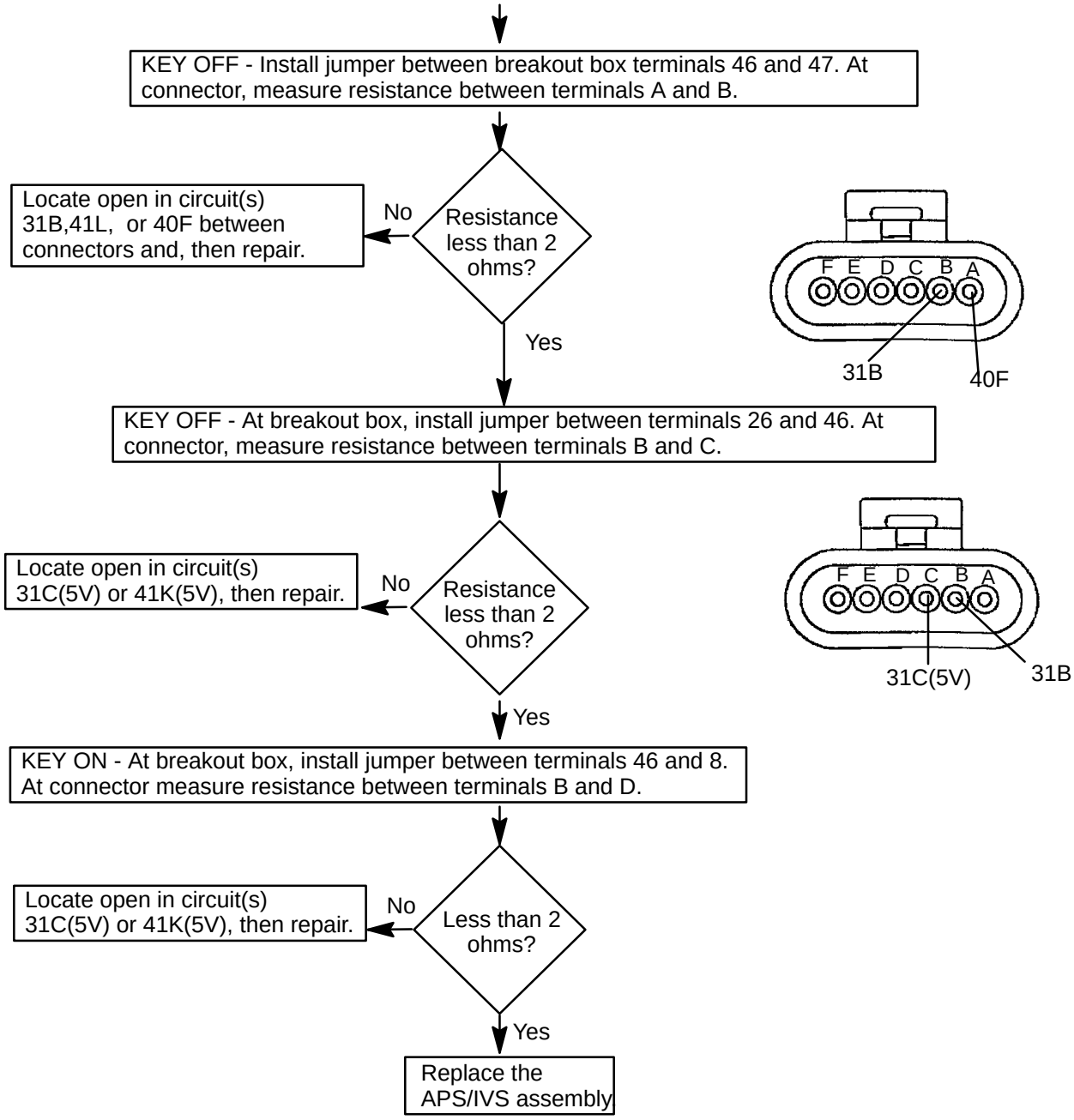
TESTING (IVS) IDLE VALIDATION SWITCH AND CIRCUITS

Note: Perform this test if codes 131 or 132 are present. If codes 133, 134 or 135 are present, perform test of IVS circuits **before** performing this test.


Begin
KEY OFF - Install breakout box to ECM harness connector, but do not connect to ECM. Disconnect APS/IVS from harness.
KEY ON - At breakout box, measure voltage between terminal 60 (GRD) and terminals 8, 26, 46 and 47.
Voltage less than 1 volt at each terminal?
No
Locate short to unwanted voltage source in circuit(s) where more than 1 volt is present, then repair.
Yes
KEY OFF - At breakout box, measure resistance between terminal 60 (GRD) and terminals 8, 26, 46, and 47.
Resistance is 100K ohms or more?
No
Locate short to ground in circuit where terminal resistance is less than 100K ohms, then repair.
Yes
KEY OFF - At breakout box, measure resistance between terminals 8, 26, 46, 47.
Resistance is 100K ohms or more?
No
Locate short between any circuits where resistance is less than 100K ohms, then repair.
Yes
F E D C B A
31B(5V)
40F
See next page

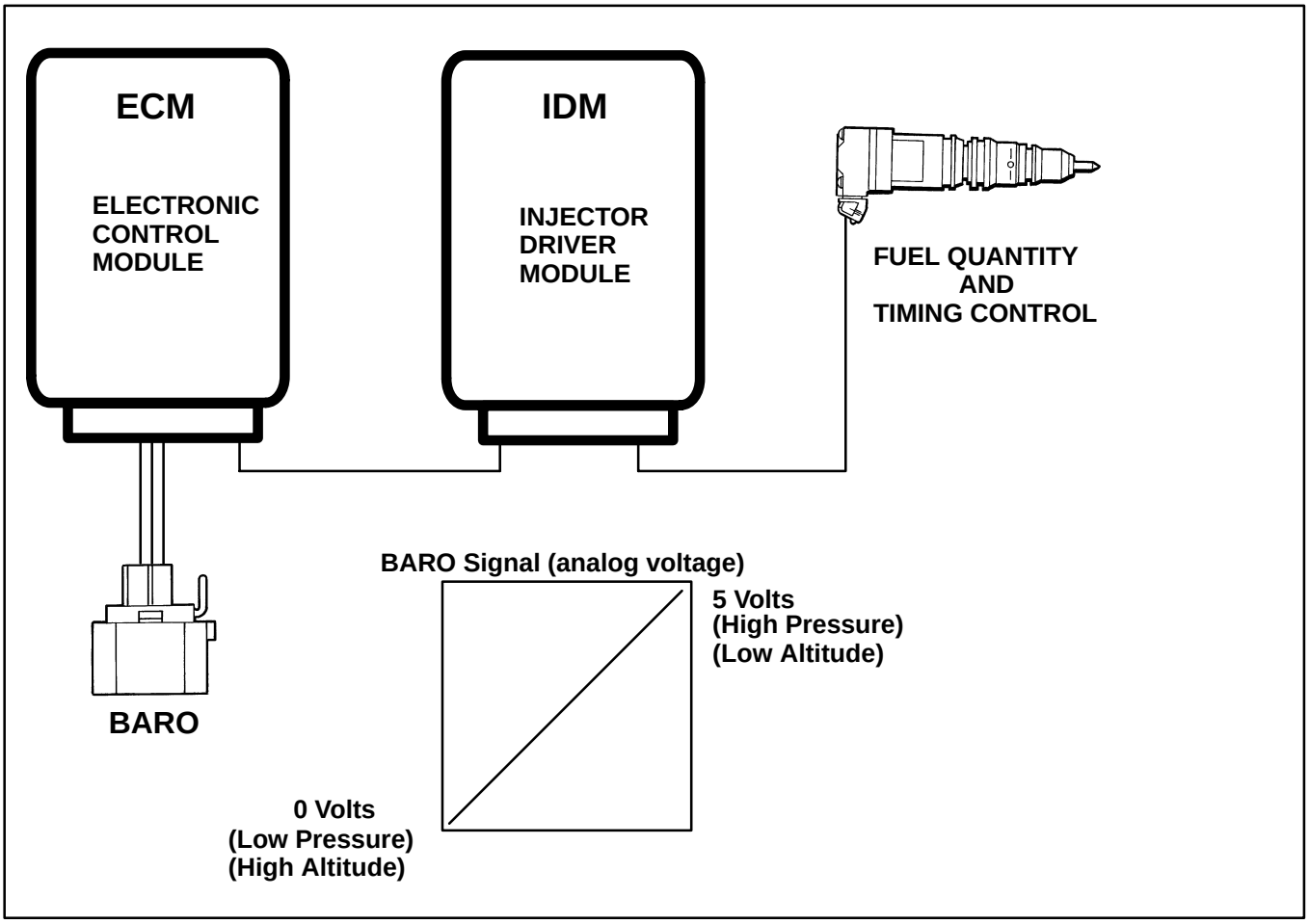
APS/IVS - Accelerator Position Sensor (Cont.)

TESTING (IVS) IDLE VALIDATION SWITCH AND CIRCUITS


KEY OFF - Install jumper between breakout box terminals 46 and 47. At connector, measure resistance between terminals A and B.
Resistance less than 2 ohms?
No
Locate open in circuit(s) 31B,41L, or 40F between connectors and, then repair.
Yes
F E D C B A
31B
40F
KEY OFF - At breakout box, install jumper between terminals 26 and 46. At connector, measure resistance between terminals B and C.
Resistance less than 2 ohms?
No
Locate open in circuit(s) 31C(5V) or 41K(5V), then repair.
Yes
F E D C B A
31C(5V)
31B
KEY ON - At breakout box, install jumper between terminals 46 and 8. At connector measure resistance between terminals B and D.
Less than 2 ohms?
No
Locate open in circuit(s) 31C(5V) or 41K(5V), then repair.
Yes
Replace the APS/IVS assembly

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BARO - Barometric Pressure Sensor



SIGNAL FUNCTIONS

The BARO (Barometric Pressure) sensor is a variable capacitance sensor that when supplied with a 5 volt reference signal from the ECM produces a linear analog voltage signal that indicates pressure.

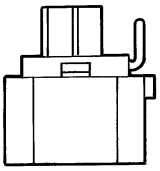
Timing Control - The BARO signal is used to determine altitude to adjust timing and fuel quantity to optimize engine operation and control smoke throughout all altitude conditions.

FAULT DETECTION/MANAGEMENT

A BARO signal that is detected out of range high or low by the ECM will cause the ECM to ignore the BARO signal and use the Manifold Absolute Pressure (MAP) signal generated at low idle as an indication of barometric pressure. If a MAP fault is detected, the BARO will default to 29.6 in. Hg. of barometric pressure.

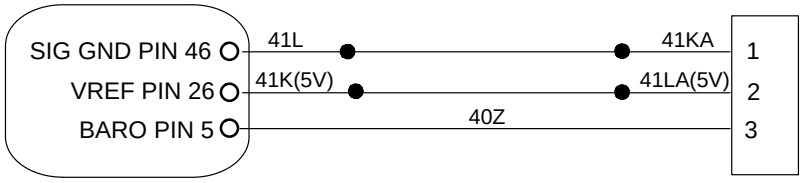
BARO - Barometric Pressure Sensor (Cont.)

Barometric Pressure Sensor (BARO)

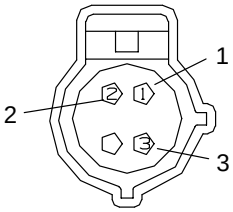


Fault Codes:
151 Out of Range High
152 Out of Range Low

ECM CONNECTOR



BARO SENSOR CONNECTOR



After removing connectors always check for damaged pins, corrosion, loose terminals etc.

Connector Checks to Ground
(Check with Sensor Connector (406) Disconnected and Ignition key off, all accessories off)

Test Points	Spec.	Comments
1 to Grd.	< 5 ohms	Resistance to grd, check with key off, > than 5 ohms the harness is open.
2 to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.
3 to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.

Connector Voltage Checks
(Check with sensor Connector (406) Disconnected, Ignition Key On, all accessories off)

Test Points	Spec.	Comments
2 to Grd.	5 Volts + .5	VRef, check with key ON, if voltage not is spec., see VRef circuit
3 to Grd.	0 - .25 v	If voltage is greater than .25 v, signal wire is shorted to Vref or battery.

Harness Resistance Checks
(Check with breakout box installed on engine harness only)

Test Points	Spec.	Comments
#46 to 1	< 5 ohms	Resistance from sensor connector to 60 pin connector - Signal ground
#26 to 2	< 5 ohms	Resistance from sensor connector to 60 pin connector - VRef
#5 to 3	< 5 ohms	Resistance from sensor connector to 60 pin connector - BARO signal

Operational Voltage Checks
(Check with breakout box installed in line with the ECM)

Test Points (+) #5 to (-) #46

Voltage	In. Hg.	kPA	Comments
4.89	31.0905	105	High atmospheric pressure
4.6	29.61	100	Normal atmospheric pressure at sea level.
2.6	17.766	60	Normal atmospheric pressure at 10,000 feet.

Fault Code Descriptions

151 = Signal voltage was greater than 4.95 volts for more than 1.0 seconds.
152 = Signal voltage was less than 1.0 volts for more than 1.0 seconds.

BARO - Barometric Pressure Sensor (Cont.)

EXTENDED DESCRIPTION BAROMETRIC PRESSURE SENSOR

Refer to circuit diagram on previous page for the following discussion.

BAROMETRIC PRESSURE SENSOR (BARO) OPERATION

The ECM sends a regulated 5 volt signal from ECM connector terminal 26 to BARO connector terminal 2. The BARO sensor returns a variable voltage signal (represents atmospheric pressure) from BARO connector terminal 3 to the ECM at terminal 5. The BARO sensor is grounded from connector terminal 1 to the ECM signal ground terminal 46.

ECM DIAGNOSTICS

The ECM continuously monitors the signal from the BARO sensor to ECM terminal 5. If the signal is out of the expected range, a fault is logged (warning light does NOT turn on) and the ECM uses the Manifold Absolute Pressure (MAP) signal generated at low idle to determine barometric pressure.

FLASH CODE *151*

ATA CODE PID 108 FMI 3

ECM: *BARO SIGNAL OUT OF RANGE HIGH*

BARO signal greater than 4.95 volts for more than 1 second.

FLASH CODE *152*

ATA CODE PID 108 FMI 4

ECM: *BARO SIGNAL OUT OF RANGE LOW*

BARO signal less than 1.0 volt for more than 1 second**.**

TROUBLESHOOTING

The BARO circuits operate with low current levels. When troubleshooting, pay special attention to the connectors.

BEFORE PERFORMING ANY TEST

Inspect connectors for pushed back, damaged, corroded or dirty terminals, as well as making sure that the terminals and wires are properly crimped. Make sure the connectors are properly joined together. Also check for any damage to the wiring and make sure system grounds are clean and tight.

TESTING APS/IVS CIRCUITS

NOTE: *If fault codes indicate a problem is also present with the APS/IVS system, troubleshoot that system before performing the following test.*

- If BARO flash code 151 or 152 is active, perform Testing Barometric Pressure Sensor Circuits.

This test systematically checks the BARO circuits for:

A. Short circuits to ground.

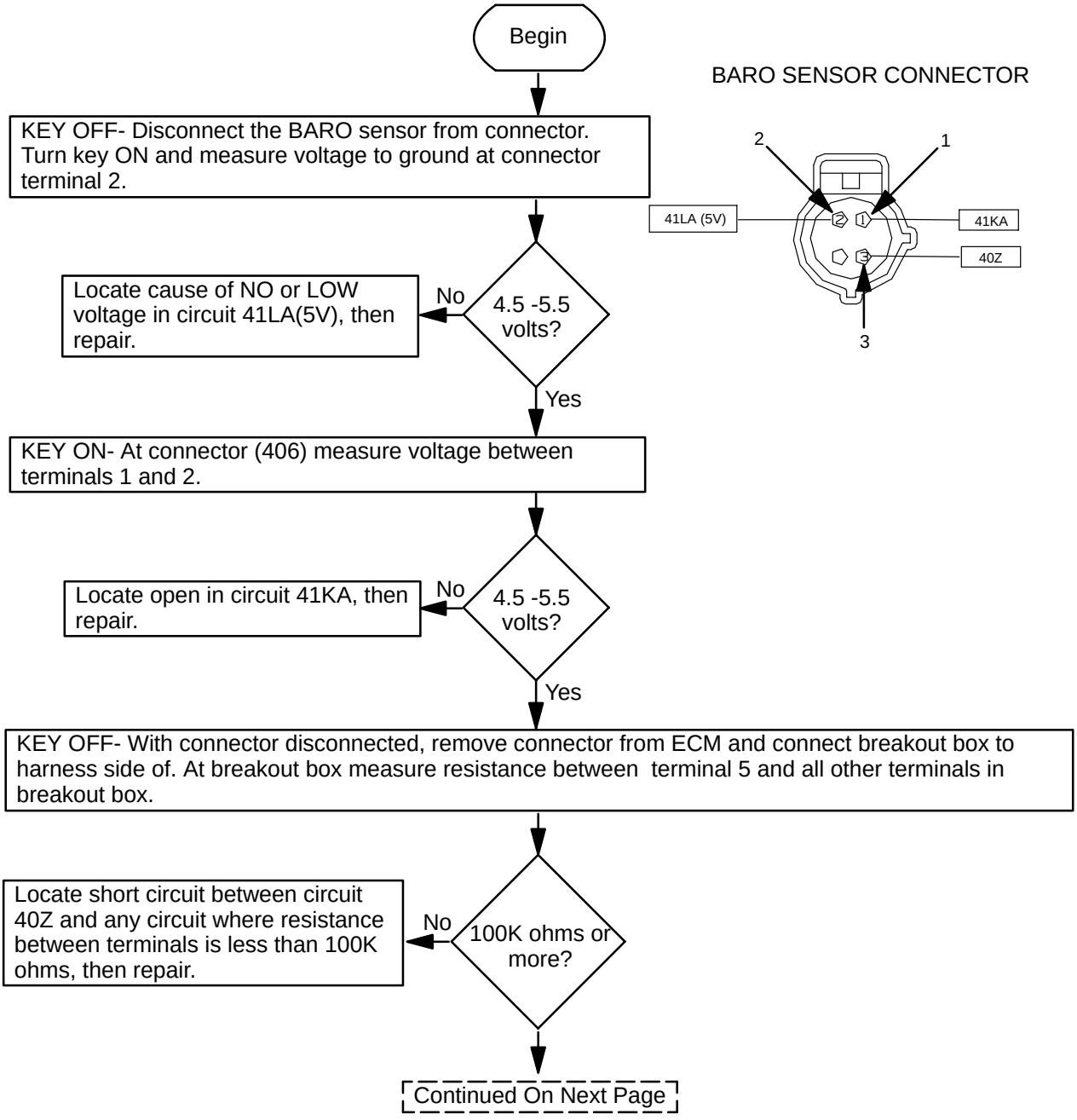
B. Short circuits to unwanted voltage sources.

C. Open circuits or excessive circuit resistance.

D. Proper feeds and grounds.

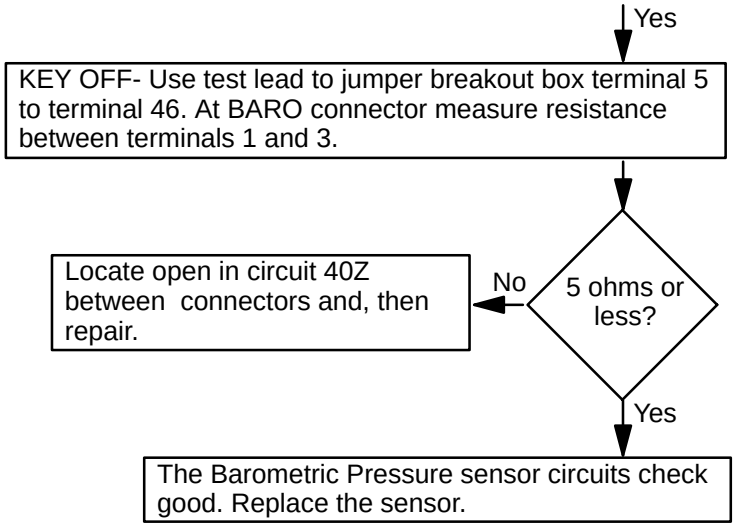
BARO - Barometric Pressure Sensor (Cont.)

TESTING BAROMETRIC PRESSURE SENSOR CIRCUIT

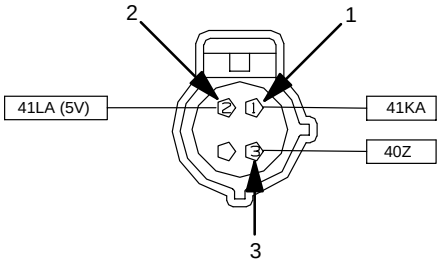

Begin
KEY OFF- Disconnect the BARO sensor from connector. Turn key ON and measure voltage to ground at connector terminal 2.
4.5 -5.5 volts?
No
Locate cause of NO or LOW voltage in circuit 41LA(5V), then repair.
Yes
KEY ON- At connector (406) measure voltage between terminals 1 and 2.
4.5 -5.5 volts?
No
Locate open in circuit 41KA, then repair.
Yes
KEY OFF- With connector disconnected, remove connector from ECM and connect breakout box to harness side of. At breakout box measure resistance between terminal 5 and all other terminals in breakout box.
100K ohms or more?
No
Locate short circuit between circuit 40Z and any circuit where resistance between terminals is less than 100K ohms, then repair.
Continued On Next Page
BARO SENSOR CONNECTOR
2
1
41LA (5V)
41KA
40Z
3

BARO - Barometric Pressure Sensor (Cont.)

TESTING BAROMETRIC PRESSURE SENSOR CIRCUIT

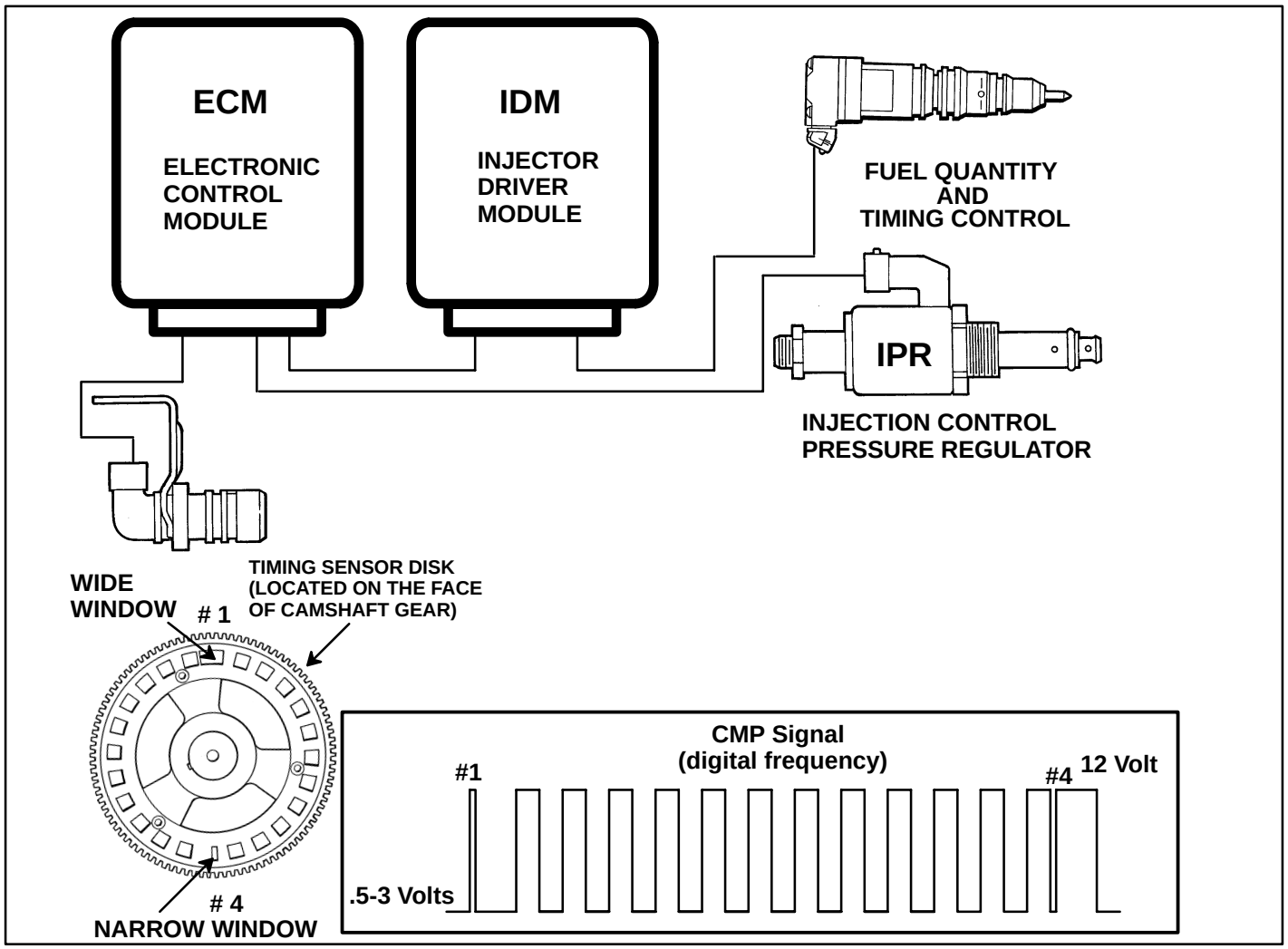

Yes
KEY OFF- Use test lead to jumper breakout box terminal 5 to terminal 46. At BARO connector measure resistance between terminals 1 and 3.
5 ohms or less?
No
Locate open in circuit 40Z between connectors and, then repair.
Yes
The Barometric Pressure sensor circuits check good. Replace the sensor.

BARO SENSOR CONNECTOR



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Camshaft Position (CMP) Sensor



SIGNAL FUNCTIONS

The CMP (Camshaft Position) sensor is a Hall Effect type sensor that generates a digital frequency as windows on the timing disk pass through its magnetic field. The frequency of the windows passing by the sensor as well as the width of selected windows allows the ECM to detect engine speed and position.

Engine Speed - Is determined by counting 24 windows on the timing sensor disk each camshaft revolution.

Fuel Timing Control - The position of cylinder #1 and #4 is determined by distinguishing a narrow or wide window on the camshaft timing sensor disk.

Engine Mode Selection - Allows the ECM to discern when the engine is in the off, crank or run mode.

Injection Control Pressure - Engine speed is one of the controlling variables in the calculation of desired injection control pressure.

Exhaust Back Pressure - Exhaust back pressure control is a function of engine speed and load.

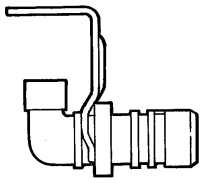
Fuel Quantity Control/Torque Limiting - Engine torque and fuel is controlled and is dependent on engine speed. Fuel quantity is determined by engine speed.

FAULT DETECTION/MANAGEMENT

An inactive CMP signal during cranking is detectable by the ECM. An inactive CMP signal will cause a no start condition. Electrical noise can also be detected by the ECM, if the level is sufficient to effect engine operation a corresponding fault code will be set. ***The engine will not operate without a functioning CMP signal.***

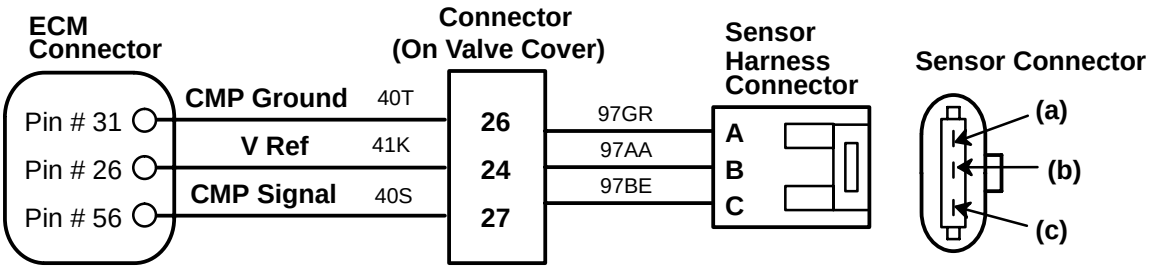
Camshaft Position (CMP) Sensor (Cont.)

Camshaft Position Sensor (CMP)



Fault Codes:

143 CMP/SYNC Counts incorrect
144 Noise Rejection
145 Inactive CMP sensor
612 Incorrect ECM/Timing Wheel



After removing connector always check for damaged pins, corrosion, loose terminals etc.

Connector Checks to Ground
(Check with Sensor Connector Disconnected and Ignition key off, all accessories off)

Test Points	Spec.	Comments
A to Grd.	< 5 ohms	Resistance to ground check with key off, if > than 5 ohms harness is open.
B to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.
C to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.

Connector Voltage Checks
(Check with Sensor Connector Disconnected and Ignition Key On)

Test Points	Spec.	Comments
B to Grd.	5 ± .5 volts	VRef check key on, VRef not present check open/short to grd #26 to B, see VRef circuit.
C to Grd.	12 ± 1.5 volts	If < than 10.5 vcheck for poor connection; if 0 vcheck for open/short to grd circuit.

Harness Resistance Checks
(Check with breakout box installed on engine harness only with ignition key Off)

Test Points	Spec.	Comments
#31 to A	< 5 ohms	Resistance from harness connector to 60 pin connector - Signal grd (CMP has dedicated grd circuit)
#26 to B	< 5 ohms	Resistance from harness connector to 60 pin connector - V Ref.
#56 to C	< 5 ohms	Resistance from harness connector to 60 pin connector - CMP signal

Operational Voltage Checks
(Check with breakout box installed in line with the ECM and ignition key ON)

Test Points (+) #56 to (-) #31		
Voltage	Position	Comments
12 ± 1.5v	Vane	With the breakout box installed, the CMP sensor & ECM connected, bar engine by hand.
.5v to 3v	Window	The CMP signal voltage should change voltage state as timing wheel on cam is rotated.

Fault Code Descriptions

143 = Incorrect number of sync to transition counts detected, possible intermittent CMP sensor/circuit fault

144 = Electrical noise detected, check wire routing and grounds

145 = Inactive CMP signal detected during engine cranking when ICP pressure was sufficient for starting

612 = ECM/target disk mismatch detected (wrong ECM installed)

CAMSHAFT POSITION SENSOR (CMP) EXTENDED SYSTEM DESCRIPTION

FUNCTION

The Navistar engine control system includes a Camshaft Position Sensor (CMP). This sensor provides the Electronic Control Module (ECM) with a signal that indicates camshaft position and engine speed.

The CMP sensor signal is used by the ECM to synchronize piston position to injector firing sequence. The injector firing order sequence begins when the ECM detects the narrow vane on the timing disk indicating #1 cylinder. Engine position for each cylinder is then continuously calculated as each vane on the timing disk passes by the CMP sensor. This information is processed by the ECM and used for injection timing and fuel delivery control. The ECM can then initiate the beginning of firing.

OPERATION

The Camshaft Position Sensor is a Hall Effect type sensor that generates a digital frequency as windows on the timing disk pass through the magnetic field. The frequency of the windows passing by the sensor as well as the width of selected windows allows the ECM to detect engine speed and position. When the narrow vane passes the CMP sensor the signal on time is less than when the other vanes pass the sensor. This produces a signal that the ECM uses to indicate engine position.

Engine speed is detected by the ECM by counting the frequency of the 24 signal pulses for each camshaft revolution.

ECM DIAGNOSTICS

Once the ECM has recognized the narrow vane (wide window) it will synchronize the engine firing order to the timing of the CMP signal. Every 2 crankshaft revolutions it will verify that synchronization. If the ECM receives too many or too few pulses for the number of engine revolutions, it will set a fault code.

The engine will not operate without a functioning CMP signal. However, the ECM will attempt to determine the cause of an invalid signal and identify it with a fault code.

CMP codes that are set will become inactive codes if the key is turned off. These codes can be retrieved using the Self Test Input (STI) switch (at instrument panel) or the Electronic Service Tool.

FLASH CODE *143*

ATA CODE SID 21 FMI 2

WRONG # OF CMP SIGNAL TRANSITIONS PER CAM REVOLUTION

Code 143 indicates the ECM has received CMP signals with the wrong number of transitions. This indicates that the ECM has counted the voltage transitions and found less than the specified number of pulses from the sensor. When this problem is continuous, the engine will stop running and the ECM will log an active code. If the key is shut off, the code will become an inactive code. This code will not turn the warning light on.

Possible causes for code 143: Intermittent CMP signal caused by an intermittent circuit, defective Camshaft Position Sensor, or incorrect CMP sensor to timing disk clearance.

FLASH CODE *144*

ATA CODE SID 21 FMI 2

CMP SIGNAL NOISE DETECTED

Code 144 indicates that the ECM has detected voltage spikes or transitions other than the CMP signal. If this problem is continuous the engine could stop running and the ECM will log an active code. If the key is shut off, the code will become an inactive code. This code will not cause the warning light to illuminate.

Code 144 may be due to: Poor ground connections for CMP or other electronic components. Wire harness shielding missing or incorrectly installed on the engine harness. Outside components that could induce voltage signals.

CAMSHAFT POSITION SENSOR (CMP)
EXTENDED SYSTEM DESCRIPTION (CONT)

FLASH CODE *145*

ATA CODE SID 21 FMI 12

CMP SIGNAL INACTIVE WHILE ICP HAS INCREASED

Flash code 145 indicates that the ECM does not detect a CMP signal. This code would be set if the engine was rotating and the ECM detected a rise in ICP pressure, but did not detect a CMP signal. To set this code the engine must be rotated long enough for the ICP to increase. When this code is set the engine will not operate. This code will not cause the warning light to illuminate.

Possible causes for flash code 145: Defective CMP sensor, faulty sensor circuitry, or improper air gap between sensor and camshaft timing disk.

FLASH CODE *612*

ATA CODE SID 21 FMI 7

INCORRECT ECM INSTALLED FOR CMP TIMING DISK

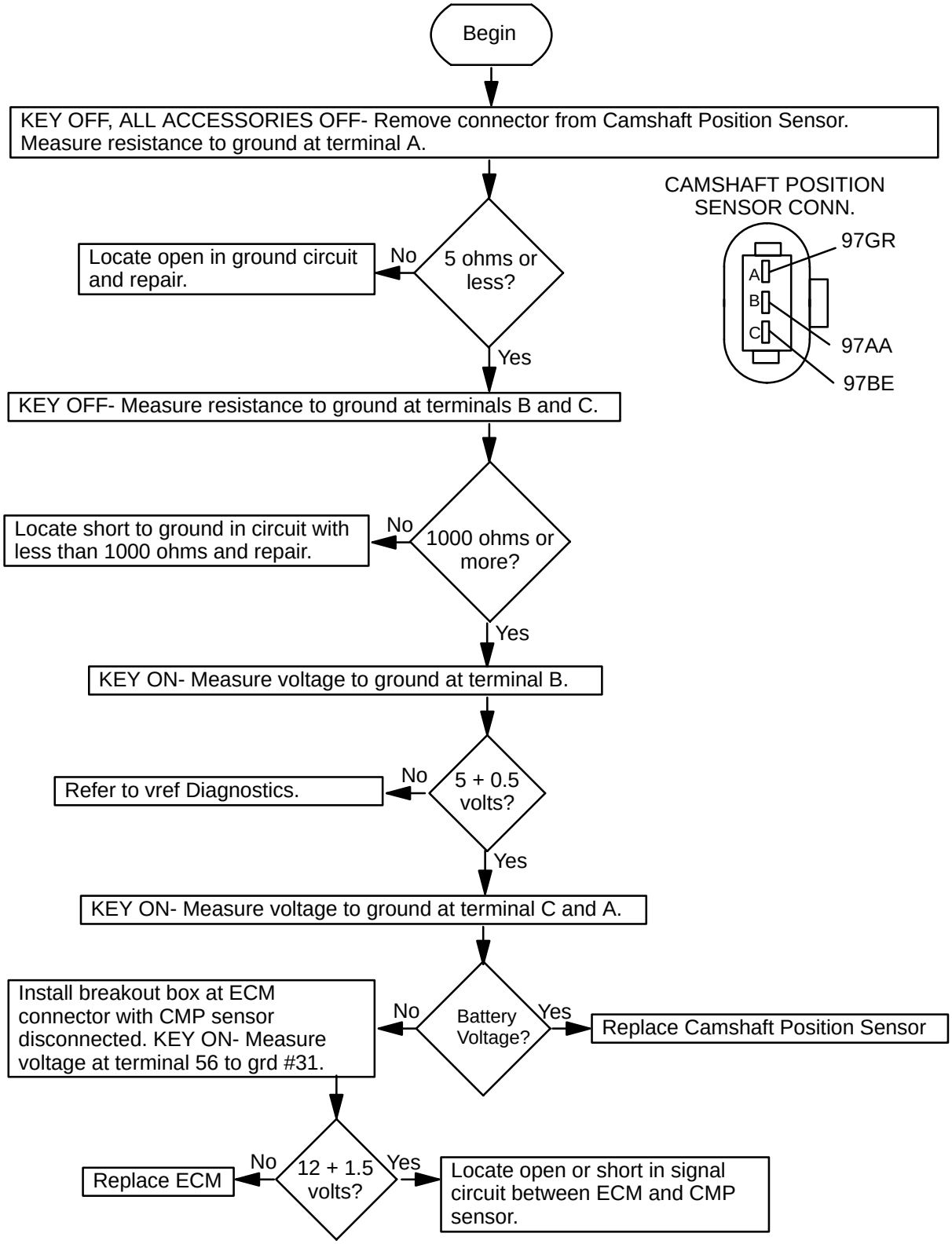
Flash code 612 indicates that the ECM has monitored the CMP signal and the signal is incorrect for the programming in the ECM. This means that the ECM does not recognize the signal generated from the timing disk and CMP sensor.

When this condition exists, the ECM does not send a Fuel Demand Command Signal (FCDS) to the Injector Drive Module (IDM). The engine cannot operate without a FDCS signal from the ECM.

Possible causes: ECM has been accidently replaced with an incorrect ECM for the particular engine application. Incorrect signal due to a defective CMP sensor or incorrect air gap between the CMP sensor and the timing disk.

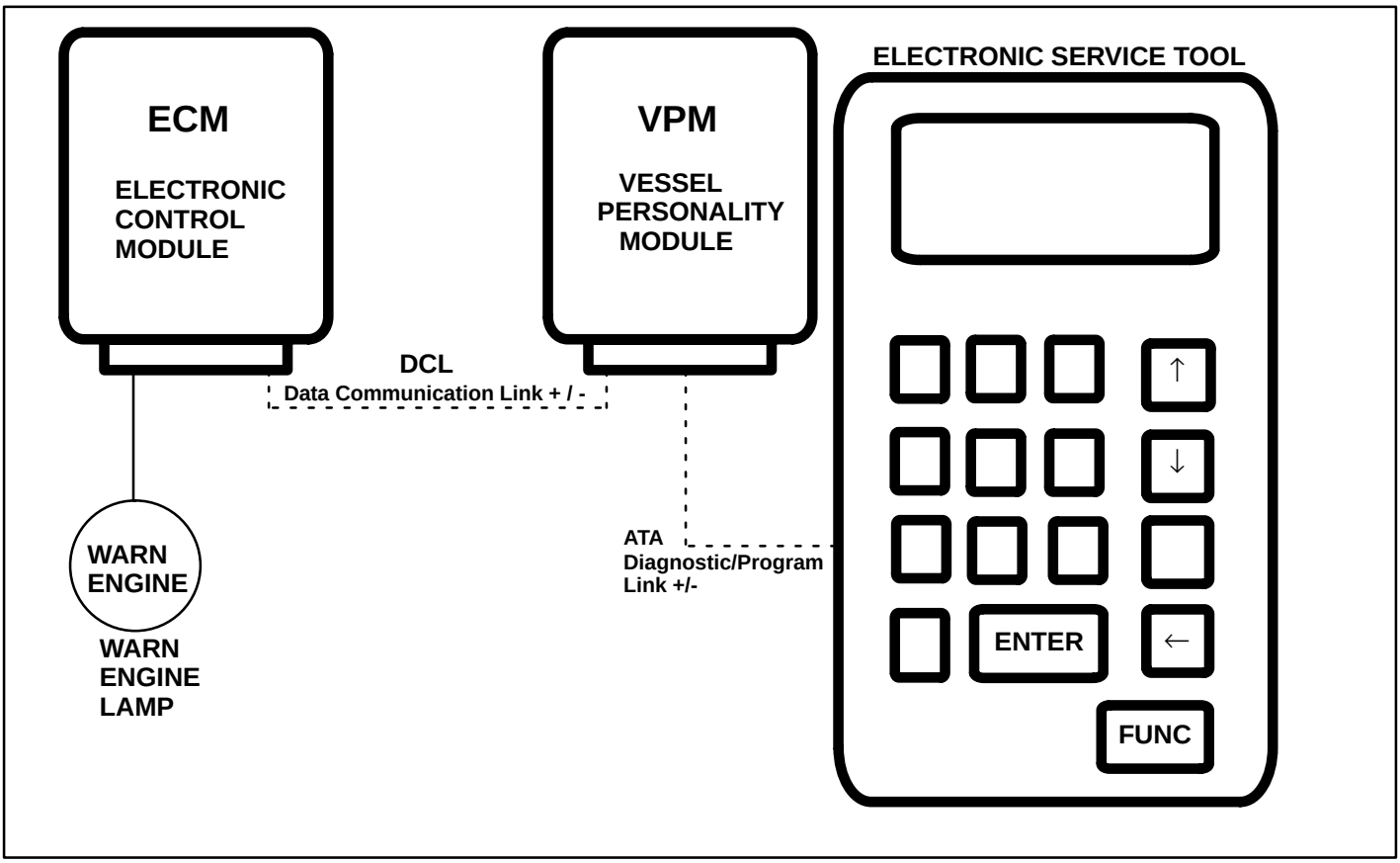
Camshaft Position (Cmp) Sensor (Cont.)

CAMSHAFT POSITION SENSOR (CMP) CIRCUIT DIAGNOSTICS


Begin
KEY OFF, ALL ACCESSORIES OFF- Remove connector from Camshaft Position Sensor. Measure resistance to ground at terminal A.
5 ohms or less?
No
Locate open in ground circuit and repair.
Yes
KEY OFF- Measure resistance to ground at terminals B and C.
1000 ohms or more?
No
Locate short to ground in circuit with less than 1000 ohms and repair.
Yes
KEY ON- Measure voltage to ground at terminal B.
5 + 0.5 volts?
No
Refer to vref Diagnostics.
Yes
KEY ON- Measure voltage to ground at terminal C and A.
Battery Voltage?
No
Install breakout box at ECM connector with CMP sensor disconnected. KEY ON- Measure voltage at terminal 56 to grd #31.
Yes
Replace Camshaft Position Sensor
12 + 1.5 volts?
No
Replace ECM
Yes
Locate open or short in signal circuit between ECM and CMP sensor.
CAMSHAFT POSITION SENSOR CONN.
A
B
C
97GR
97AA
97BE

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DCL/ATA Communication Link (DCL/ATA)



SIGNAL FUNCTIONS

Data Communication Link - the Data Communication Link signal is a 0 to 5 volt variable width wave form signal that enables communication between the Vehicle Personality Module (VPM) and the ECM. It is used for communication of diagnostic and calibration data.

ATA Diagnostic/Programming Link - The ATA signal is a 0 to 5 volt width wave form signal that enables communication between the VPM and the Electronic Service Tool (EST). It is used for communication of calibration, programming and diagnostic information.

Tachometer Signal - The ECM provides the VPM with a 0 to 12 volt tachometer signal. The frequency of the signal is one-fifth (1/5th) the RPM.

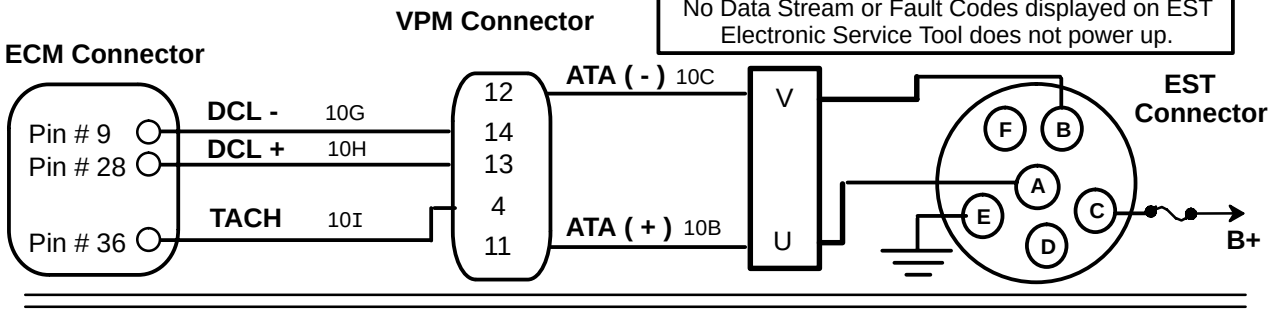
FAULT DETECTION/MANAGEMENT

The VPM and ECM can detect (on a continuous basis) an open, short or intermittent connection on the DCL and ATA lines.

DCL/ATA Communication Link (DCL/ATA) Cont.

VPM Communications
DCL ± Data Communication Link
ATA ± American Trucking Association

Fault Codes:
223 VPM Not Communicating with ECM
231 ATA Common Fault
232 Unable to Forward ECM Message to ATA DCL
234 Unable to Forward ATA Message to ECM
235 VPM/ECM DCL Fault
633 ECM/VPM Common Fault
No Data Stream or Fault Codes displayed on EST Electronic Service Tool does not power up.



After removing connector always check for damaged pins, corrosion, loose terminals etc.

Key ON Engine OFF - Voltage Checks at EST Connector

+Test Points	Spec.	Signal	Comments
C to E	B+	Power	Should be power at C at all times.

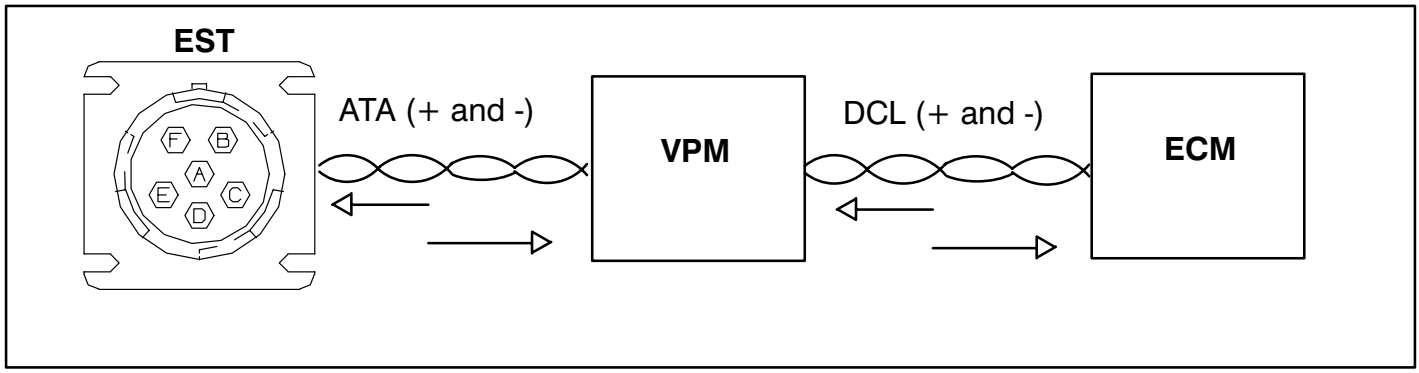
Connector Checks to Ground at ECM
(Check with breakout box installed, ignition key should be in the OFF position)

Test Points	Spec.	Signal	Comments
#9 to #46	> 1000 ohm	DCL-	< 1000 ohms indicates a short to grd. either thru the harness or internal in the ECM or VPM. Disconnect VPM and measure to grd again. If short still present, disconnect ECM and measure to grd. If short is still present, repair harness.
#28 to #46	> 1000 ohm	DCL+	

Harness Resistance Checks
(Check with breakout box installed, ignition key should be in the OFF position)

Test Points	Spec.	Signal	Comments
#9 to 14	< 5 ohm	DCL-	Resistance from 60 pin connector to harness connector - DCL Signal
#28 to 13	< 5 ohm	DCL+	Resistance from 60 pin connector to harness connector - DCL Signal
12 to B	< 5 ohm	ATA-	Resistance from VPM connector to EST connector - ATA Signal
11 to A	< 5 ohm	ATA+	Resistance from VPM connector to EST connector - ATA Signal
C to B+	< 5 ohm	PWR	Resistance from EST connector to Fuse - EST Power
E to Grd.	< 5 ohm	GRD	Resistance from EST connector to grd (ECM pin #46 if breakout box installed)

Fault Code Descriptions
223 VPM not communicating with ECM, DCL wiring faults, faulty VPM
231 ATA Common Fault - ATA wiring faults, faulty VPM
232 Unable to forward ECM message to ATA DCL - ATA wiring faults, faulty VPM
234 Unable to forward ATA message to ECM-key is off w/EST installed, DCL wiring faults, faulty ECM
235 VPM/ECM DCL Fault - DCL wiring faults, faulty ECM
633 ECM/VPM Common Fault - DCL wiring fault, SW mismatch, faulty VPM
No Data Stream or Fault Codes displayed on Electronic Service Tool
Electronic Service Tool does not power up.



EXTENDED DESCRIPTION - ECM/VPM COMMUNICATION

The engine control system includes the Electronic Control Module (ECM), Vessel Personality Module (VPM), and Injector Driver Module (IDM).

The engine control system “communicates” with the Electronic Service Tool through connector (384) as shown. The EST communicates with the VPM using the American Trucking Association (ATA) data link lines**(1)**.

The ECM communicates with the VPM through a proprietary data link channel (DCL). The Data Communications Link (DCL) channel connects the ECM and the VPM.

Both the ATA and DCL circuits use twisted wire pairs. All repairs to these pairs must maintain one complete twist per inch along the entire length of the circuits. These circuits are polarized (one positive and one negative) and reversing the polarity of these circuits will disrupt communications.

(1) - The ATA data link is defined by SAE recommended practices J1708 and J1587. This link and EST connector were adopted by the Recommended Practices 1201 and 1202.

ATA COMMUNICATIONS

Refer to the circuit diagram for the following discussion.

ATA DATA LINK CONNECTOR

All communications between the EST (Pro-link® 9000™ using the Navistar cartridge) and the engine control system, is done through the EST connector. This communications link supports:

- Displaying fault codes and operating conditions on the EST.
- Performing proprietary diagnostic tests programmed into the cartridge.
- Clearing fault codes.
- Programming performance parameter values.

The EST connector has six pins, labeled A through F, that provide the following:

a. Fused BATTERY power is provided to Pin “C” to provide battery power for electronic service tools. Pin “E” provides a battery ground for the EST.

b. Connector terminal A is connected to VPM terminal 11. Terminal B is connected to VPM terminal 12. These two terminals are provided for communication to the service tool.

EXTENDED DESCRIPTION (CONTINUED) - POSITIVE AND NEGATIVE ATA DATA LINKS

Circuit 10B and 10C connect the EST connector and the VPM.

The RED positive bus (427) is connected by circuit 98A(+) to the VPM at connector (381), terminal 11. The BLUE negative bus (428) is connected by circuit 98C(-) to the VPM at connector (381), terminal 12.

DCL COMMUNICATION LINKS

The VPM is connected to the ECM through the DCL. The DCL connection between the ECM and the VPM serves as a conduit for data sent on the ATA to be shared with the ECM. Communications between the ECM and the EST connector go through the VPM.

VPM - ECM COMMUNICATIONS

The positive (+) DCL link is circuit 10H, which connects ECM connector terminal 28, to the VPM through connector terminal 13. The negative (-) DCL link is circuit 10G, which connects ECM connector terminal 9 to the VPM through connector terminal 14. These two circuits (10H and 10G) are a twisted wire pair and pass through dash connector at terminals V and U.

Both the ATA and DCL circuits use twisted wire pairs. All repairs to these wire pairs must maintain one complete twist per inch along the entire length of the circuits. Both circuits are polarized (one positive and one negative) and reversing the polarity of the circuit will disrupt communications.

ECM DIAGNOSTICS

Flash codes that can be caused by defects occurring in the ATA or DCL circuits are discussed in this section. There are also Flash Codes related to or caused by faulty communication (corrupt or invalid data transmitted between the ECM and VPM), that are discussed in this section.

EST CONNECTOR

The engine control system does not detect faults in the power or ground circuits to EST connector. If the service tool does not power up when connected, try the service tool on another vehicle if one is available to determine if the service tool is working properly. If the service tool is OK, then perform Testing EST Connector Power and Ground Circuits.

EST DISPLAYS

Should the EST display NO DATA, the ATA data link circuit from the EST connector to the VPM may be disrupted. Verify that the key is ON and then perform Testing The ATA Data Link Circuits.

FAULT CODES

FLASH CODE *223*

ATA CODE SID 252 FMI 7

VPM NOT COMMUNICATING WITH ECM

SYMPTOM: Flash code 223 causes the engine to operate in Field Defaults, which turns the Engine Warning Light ON. When Field Defaults are being used by the ECM, Flash Code 622 also is set. If the condition causing code 223 is intermittent, and the condition is no longer present, the code will change to an inactive code, and the engine will resume normal operation.

WIRING CAUSES: DCL circuits 10H and/or 10G between the ECM and VPM: shorted Low or High or Open.

If code 223 is active:

1. Perform TESTING DCL CIRCUITS.
   a. If defect is found in DCL circuit, correct defect.
   b. If the DCL circuits (10G and 10H) check good, replace the VPM.

FLASH CODE *231*

ATA CODE SID 250 FMI 2

VPM: *ATA COMMON FAULT*

SYMPTOM: Code 231 **does not** turn Engine Warning light ON. This code can occur when the VPM can't access the ATA data link. If this occurs, there will not be any ATA data available at the electronic service tool (EST). The code can be "flashed" using the STI switch located on the instrument panel.

WIRING CAUSES: ATA positive or negative circuits between EST and VPM: Shorted (high or low), open, or busy (too many devices).

FAULT CODES (CONTINUED)

FLASH CODE *231*

ATA CODE SID 250 FMI 2

VPM: *ATA COMMON FAULT (Continued)*

If code 231 is active:

1. Perform Testing the ATA Data Link Circuits.
   a. If defect is found in ATA circuits, correct defect.
   b. If defect is not found in ATA circuits, investigate SYSTEM CAUSES.

SYSTEM CAUSES: System causes can include:

1. If no system causes are present, replace the VPM.

FLASH CODE *232*

ATA CODE SID 250 FMI 9

VPM: *UNABLE TO FORWARD ECM MESSAGE TO ATA DCL*

SYMPTOM: There are no ECM replies to requests from the EST or VPM. Flash Code 232 **does not** turn the Engine Warn Light ON.

WIRING CAUSES: The positive and/or negative ATA data link circuits between the EST and VPM (or other devices installed using the ATA link): Shorted High or Low or Open.

If code 232 is active:

1. Perform Testing the ATA Data Link Circuits.
   a. If wiring defect is found, correct defect.
   b. If no wiring defects are found, investigate System Causes.

SYSTEM CAUSES: Code 232 can occur when the ECM is sending more messages than the VPM can transmit on the ATA bus. This can be caused by:

1. May be caused by code 231 occurring.
2. If none of the system causes are present, replace the VPM.

FLASH CODE *234*

ATA CODE SID 248 FMI 9

VPM: *UNABLE TO FORWARD ATA MESSAGE TO ECM.*

SYMPTOM: There are no ECM replies to requests from the EST or VPM. There is NO Engine Warning Light. Code 223 may also be present.

NOTE: *Code 234 can be set by connecting the EST when the key is OFF. If the key was recently turned off, the VPM may still be powered. The VPM can stay on for up to 30 minutes after turning the key off. If the prolink is connected (key off), the VPM will unsuccessfully request data from the ECM, which is not powered with the key off. If this occurs, turn the key on and clear the codes.*

WIRING CAUSES: DCL positive or negative circuits (10G and/or 10H): Shorted High or Low or open between ECM and VPM.

If code 234 is active:

1. Verify that ignition key is ON.
2. Perform Testing DCL Data Link Circuits.
   a. If defect is found in DCL, correct defect.
   b. If no defects are in DCL, replace the ECM.

FAULT CODES (CONTINUED)

FLASH CODE *235*

ATA CODE SID 248 FMI 2

VPM: *VPM/ECM DCL FAULT*

SYMPTOM: There are no ECM diagnostic replies to requests from the EST or VPM. Engine Warning Light OFF. If the condition causing code 235 to set is intermittent and the condition is no longer present, the code will go to inactive status.

WIRING CAUSES: DCL circuits 10G and/or 10H are: shorted High or Low or Open between VPM and ECM.

If code 235 is active, Perform Testing DCL Data Link Circuits.

1. If wiring defect is found, correct defect.
2. If wiring defect is not found, replace the ECM.

FLASH CODE *633*

ATA CODE SID 252 FMI 2

ECM: *ECM/VPM COMMON FAULT*

SYMPTOM: The engine operates on Field Defaults turning the Engine Warning Light ON and setting code 622.

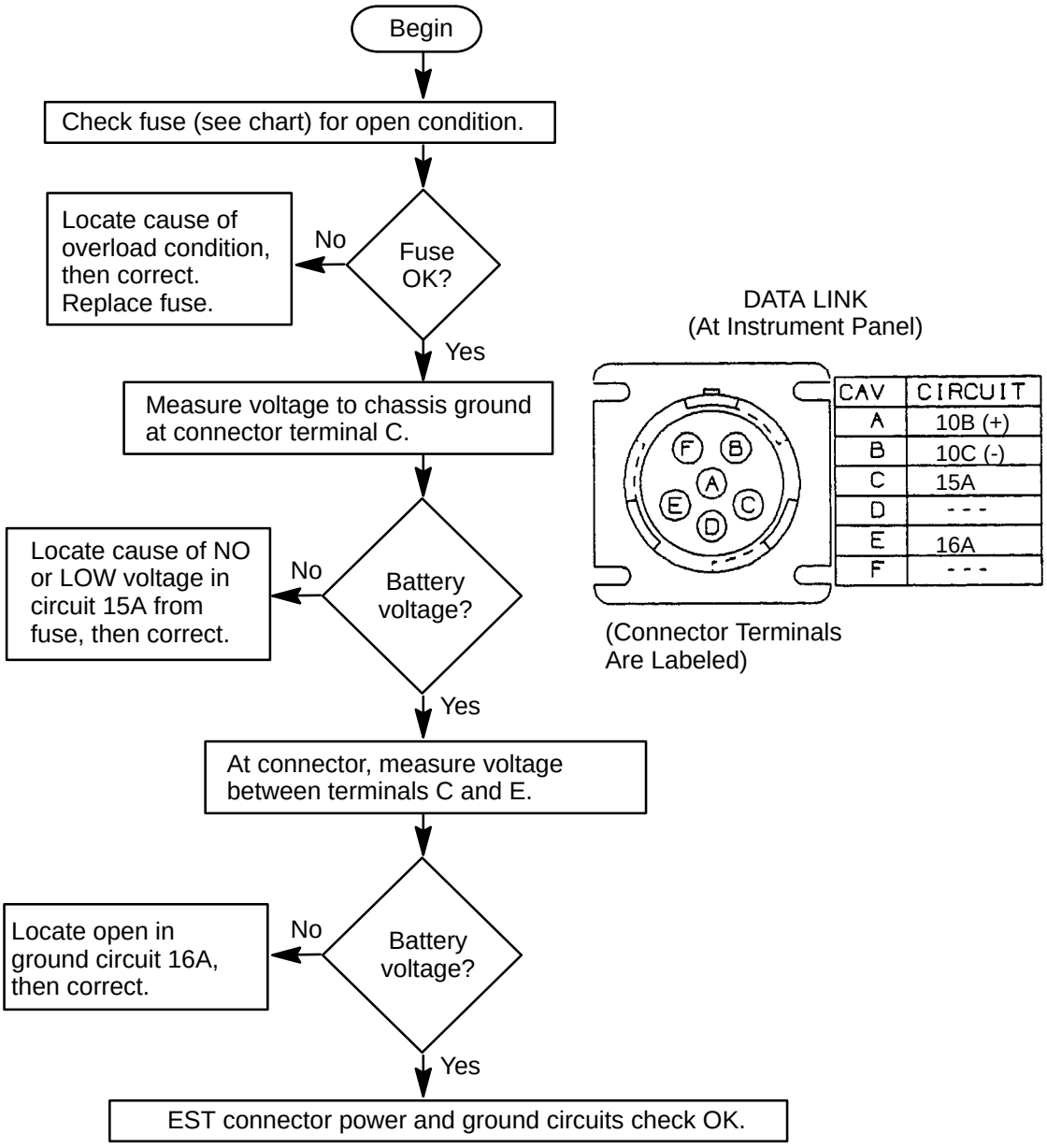
This code indicates that the ECM and VPM are communicating incorrectly. The message from the VPM contains bad data, or the VPM takes too long to respond to ECM requests for data. If this code is caused by an intermittent condition, and the condition is no longer present, the code will become inactive and normal engine operation will resume.

WIRING CAUSES: DCL circuits 10G or 10H between ECM and VPM are: shorted Low, High or Open.

If code 633 is active:

1. Perform Testing DCL Data Link Circuits.
    a. If defect is found in DCL, correct.
    b. If there are no defects in the DCL, refer to codes 613 and 614 and verify that the ECM and VPM have the correct software versions. If the software versions are correct, replace the VPM.

TESTING EST CONNECTOR (384) POWER AND GROUND CIRCUITS



TROUBLESHOOTING

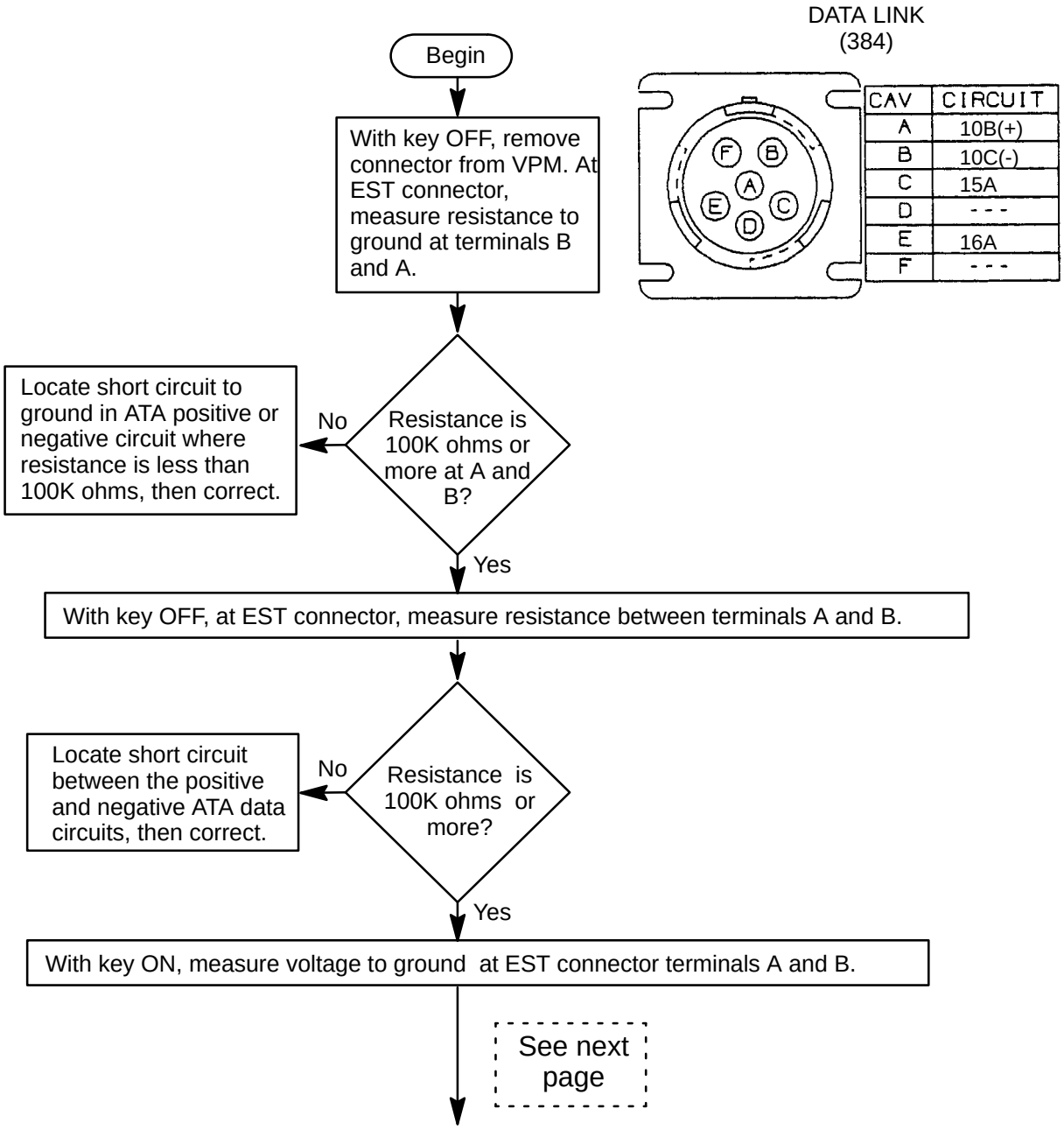
The DCL and ATA circuits operate with very low current levels. When troubleshooting the DCL or ATA, pay special attention to the connectors.

BEFORE PERFORMING ANY TEST

Inspect for pushed back, damaged, corroded or dirty terminals as well as making sure that the terminal and wire are properly crimped. Make sure the connectors are properly joined together. Also check for damage to wiring, and clean tight ground connections.

DCL/ATA Communication Link (DCL/ATA) Cont.

TESTING THE– ATA DATA LINK CIRCUITS



DCL/ATA Communication Link (DCL/ATA) Cont.

TESTING THE ATA DATA LINK CIRCUITS (CONTINUED)

Voltage is 1.0 volts or more?

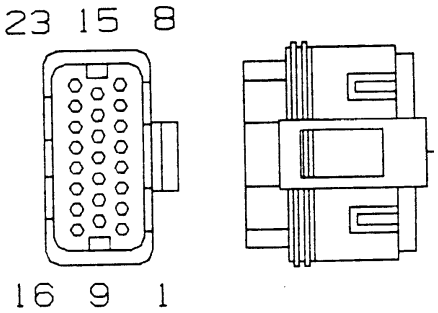
No

Locate short circuit to unwanted voltage source in ATA positive or negative circuit where voltage is greater than 1.0 volt, then correct.

Yes

KEY OFF - Remove ECM Power Fuse. At VPM connector measure resistance between terminal 11, cir 10B (+) and terminal 12, 10C (-) and all other terminals in VPM connector.

VPM CONNECTOR



100K ohms or more between all terminals?

No

Locate short circuit between any circuits, where resistance between terminals is less than 100K ohms, then correct.

Yes

KEY OFF - Measure resistance between VPM connector terminal 11, cir 10B (+) and EST connector terminal A.

Resistance is less than 2.0 ohms?

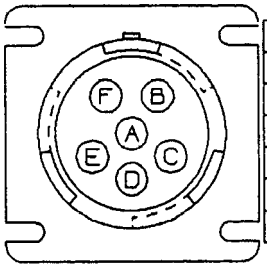
No

Locate open or cause of high resistance in circuit 10B (+) between VPM connectors and data link connector, then correct.

Yes

KEY OFF - Measure resistance between VPM connector terminal 12, cir 15A(-) and EST connector terminal B.

DATA LINK



CAV	CIRCUIT
A	10B(+)
B	10C(-)
C	15A
D	- - -
E	16A
F	- - -

See next page

DCL/ATA Communication Link (DCL/ATA) Cont.

TESTING THE ATA DATA LINK CIRCUITS (CONTINUED)

Resistance is less than 2.0 ohms?

No

Locate open or cause of high resistance in circuit 15A(-)/10C(-) between VPM connector and data link connector, then correct.

Yes

KEY OFF - If an additional device is connected to the ATA bus, measure resistance between connector terminal B and the ATA (-) circuit in the device connector.

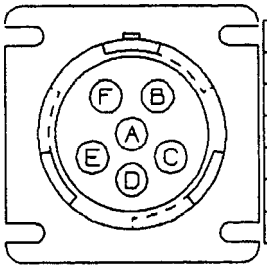
Resistance is less than 2.0 ohms?

No

Locate open in ATA (-) circuit between data link connector and device connector, then correct.

Yes

DATA LINK
(384)



CAV	CIRCUIT
A	10B(+)
B	10C(-)
C	15A
D	- - -
E	16A
F	- - -

KEY OFF - If an additional device is connected to the ATA circuit, measure resistance between data link connector terminal A and the ATA (+) circuit in the device connector.

Resistance is less than 2.0 ohms?

No

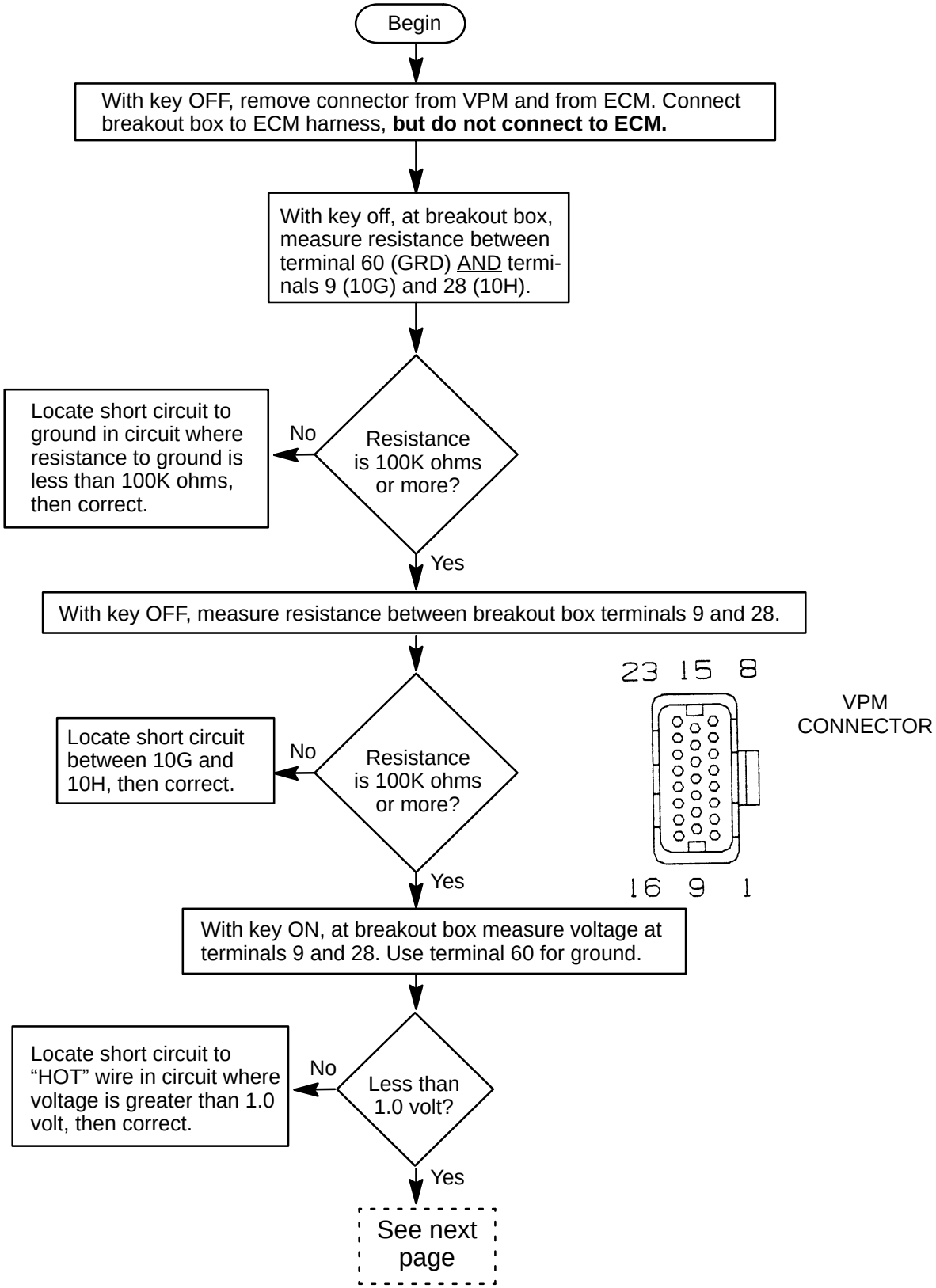
Locate open in ATA (+) circuit between data link connector and device connector, then correct.

Yes

The ATA positive and negative circuits are not shorted high or low and circuit resistance is within specifications.

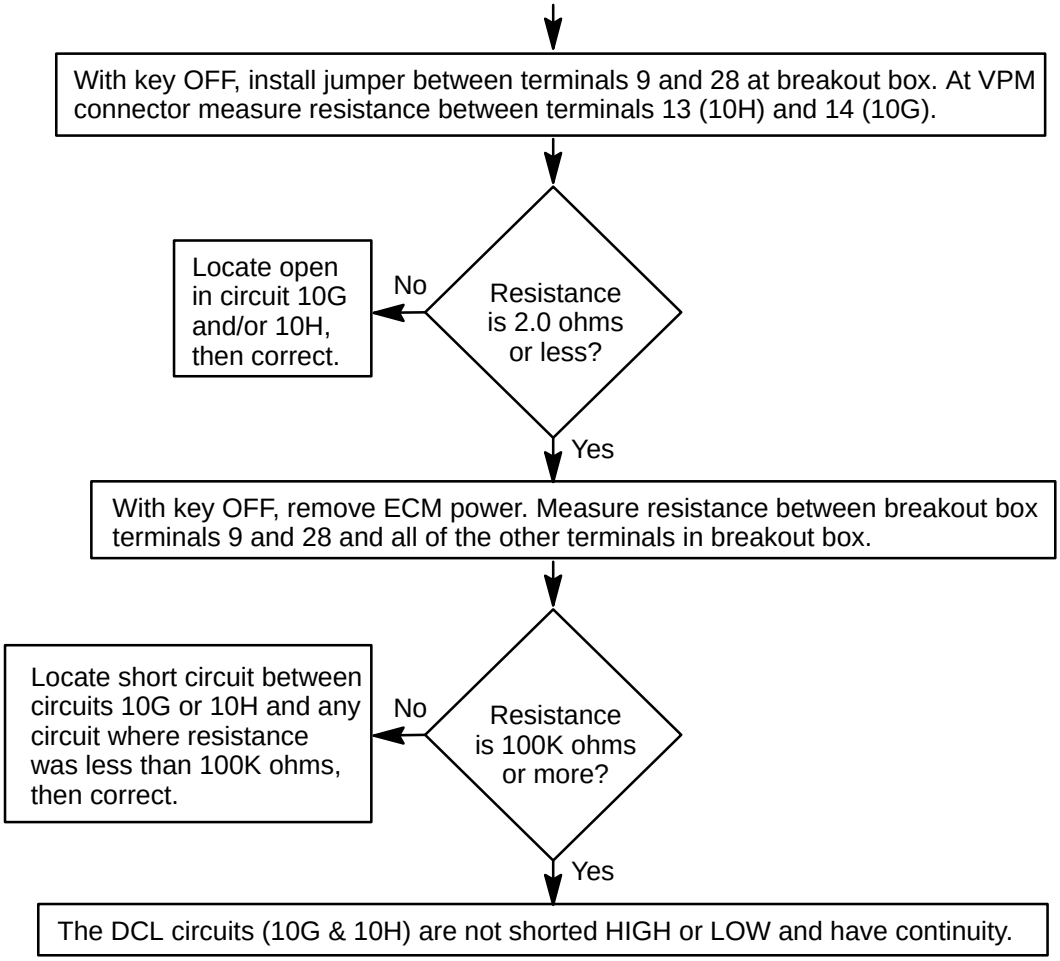
DCL/ATA Communication Link (DCL/ATA) Cont.

TESTING THE DCL DATA LINK CIRCUITS

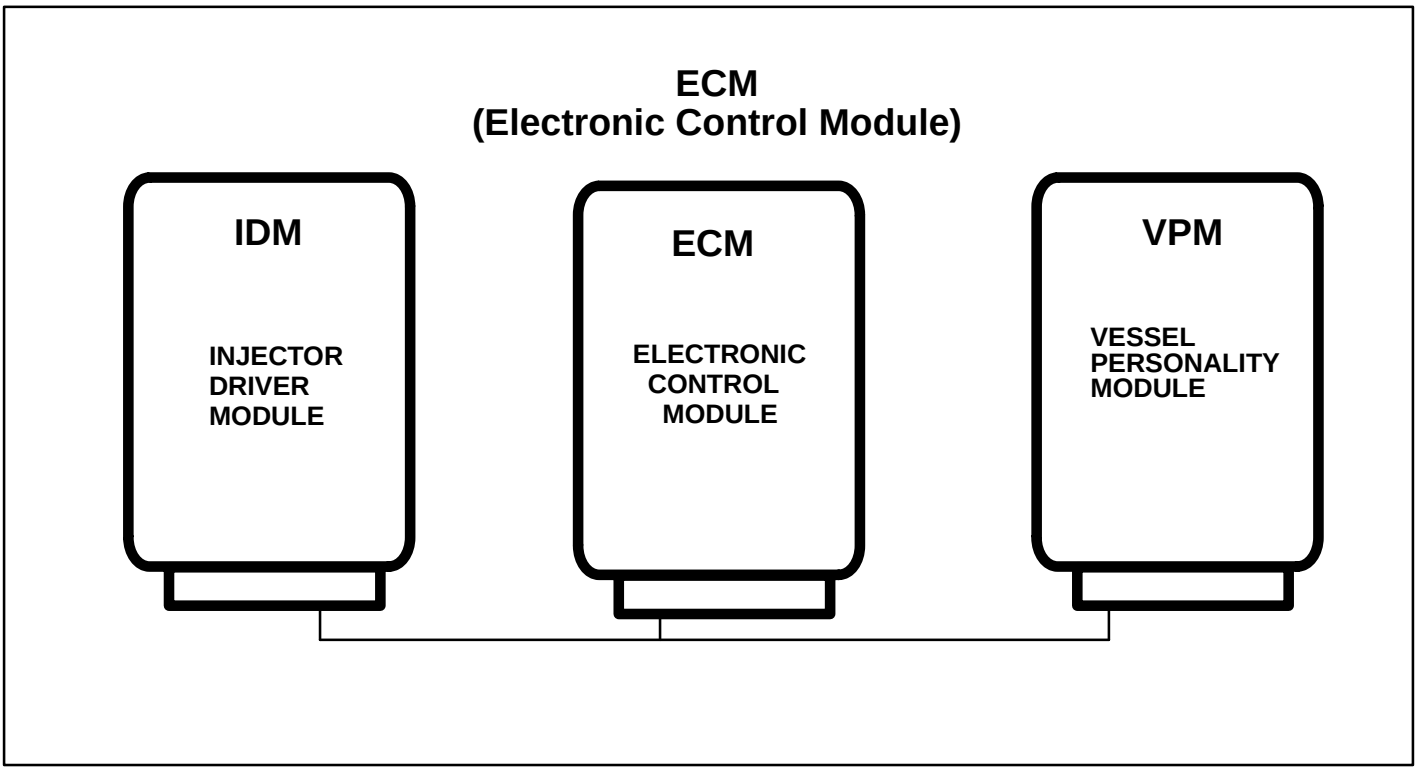

Begin
With key OFF, remove connector from VPM and from ECM. Connect breakout box to ECM harness, **but do not connect to ECM.**
With key off, at breakout box, measure resistance between terminal 60 (GRD) AND terminals 9 (10G) and 28 (10H).
Resistance is 100K ohms or more?
No
Locate short circuit to ground in circuit where resistance to ground is less than 100K ohms, then correct.
Yes
With key OFF, measure resistance between breakout box terminals 9 and 28.
Resistance is 100K ohms or more?
No
Locate short circuit between 10G and 10H, then correct.
Yes
23 15 8
16 9 1
VPM CONNECTOR
With key ON, at breakout box measure voltage at terminals 9 and 28. Use terminal 60 for ground.
Less than 1.0 volt?
No
Locate short circuit to “HOT” wire in circuit where voltage is greater than 1.0 volt, then correct.
Yes
See next page

DCL/ATA Communication Link (DCL/ATA) Cont.

TESTING THE DCL DATA LINK CIRCUITS (CONTINUED)


With key OFF, install jumper between terminals 9 and 28 at breakout box. At VPM connector measure resistance between terminals 13 (10H) and 14 (10G).
Resistance is 2.0 ohms or less?
No
Locate open in circuit 10G and/or 10H, then correct.
Yes
With key OFF, remove ECM power. Measure resistance between breakout box terminals 9 and 28 and all of the other terminals in breakout box.
Resistance is 100K ohms or more?
No
Locate short circuit between circuits 10G or 10H and any circuit where resistance was less than 100K ohms, then correct.
Yes
The DCL circuits (10G & 10H) are not shorted HIGH or LOW and have continuity.

Electronic Control Module (ECM) Self-Diagnostics



SIGNAL FUNCTION

The Electronic Control Module (ECM) monitors and controls engine operation and performance, communicates information to the Vessel Personality Module (VPM) and Injector Drive Module (IDM).

FAULT DETECTION/MANAGEMENT

The ECM is capable of internal fault detection and dependent upon the severity of the problem, can provide fault management strategies to allow limited engine operation.

Electronic Control Module (ECM) Self-Diagnostics (Cont.)

NORMAL OPERATION DIAGNOSTICS

During normal engine operation, the ECM automatically performs several tests to detect faults. During Normal Operation, the ECM performs the Start-up KAM Test and Continuous Diagnostics.

START-UP KAM TEST

The Start-up KAM Test is used to validate the ECM's Keep-Alive-Memory once each time the ECM resets (turns ON). If an error is detected, Flash codes 224 or 615 can be set.

Flash Code *615*

ATA CODE SID 254 FMI 13

ECM: *Programmable Parameter KAM Corrupt Fault*

Flash Code 615 can be set when Flash code 224 is set. If 224 is present, refer to Keep Alive Memory Power (KAM PWR) in this section to diagnose.

If code 224 IS NOT SET, code 615 indicates that the ECM's RAM is defective. Replace the ECM.

CONTINUOUS DIAGNOSTICS

Continuous diagnostic checks are made by the ECM during vehicle operation to detect out-of-range, rationality and system faults. Flash codes 112 and 113 can be set during this diagnostic process. Refer to (ECM PWR) in this section.

ON DEMAND DIAGNOSTICS (SERVICE DIAGNOSTICS)

The ECM will perform On-Demand Diagnostics (Service diagnostics) when requested by the service technician. The KOEO Standard Test Procedure includes:

- ECM Internal Self-Tests.
- Output Circuit Checks (OCC).

ECM INTERNAL SELF-TESTS

Use the Prolink EST to perform the self-tests. The test procedure checks the ECM's CPU, RAM, and ROM. The test may set the following flash codes.

Flash Code *111*

ATA CODE PID 194 FMI 0

ECM: *No Errors Detected*

Flash Code 111 indicates that the ECM has not detected any errors.

Flash Code *625*

ATA CODE SID 254 FMI 9

ECM: *ECM Inactive Background*

Code 625 indicates that the ECM Software is Faulty. Replace the ECM.

Flash Code *631*

ATA CODE SID 240 FMI 2

ECM: *ROM Test Fault*

If code 631 is present, replace the ECM.

Flash Code *632*

ATA CODE SID 254 FMI 12

ECM: *RAM/CPU Test Fault*

If code 632 is present, replace the ECM.

ECM OUTPUT CIRCUIT CHECKS (OCC)

During the OCC checks, the following ECM related codes can occur:

Flash Code *254*

ATA CODE SID 254 FMI 3

ECM: *OCC ORH*

If code 254 is present, replace the ECM.

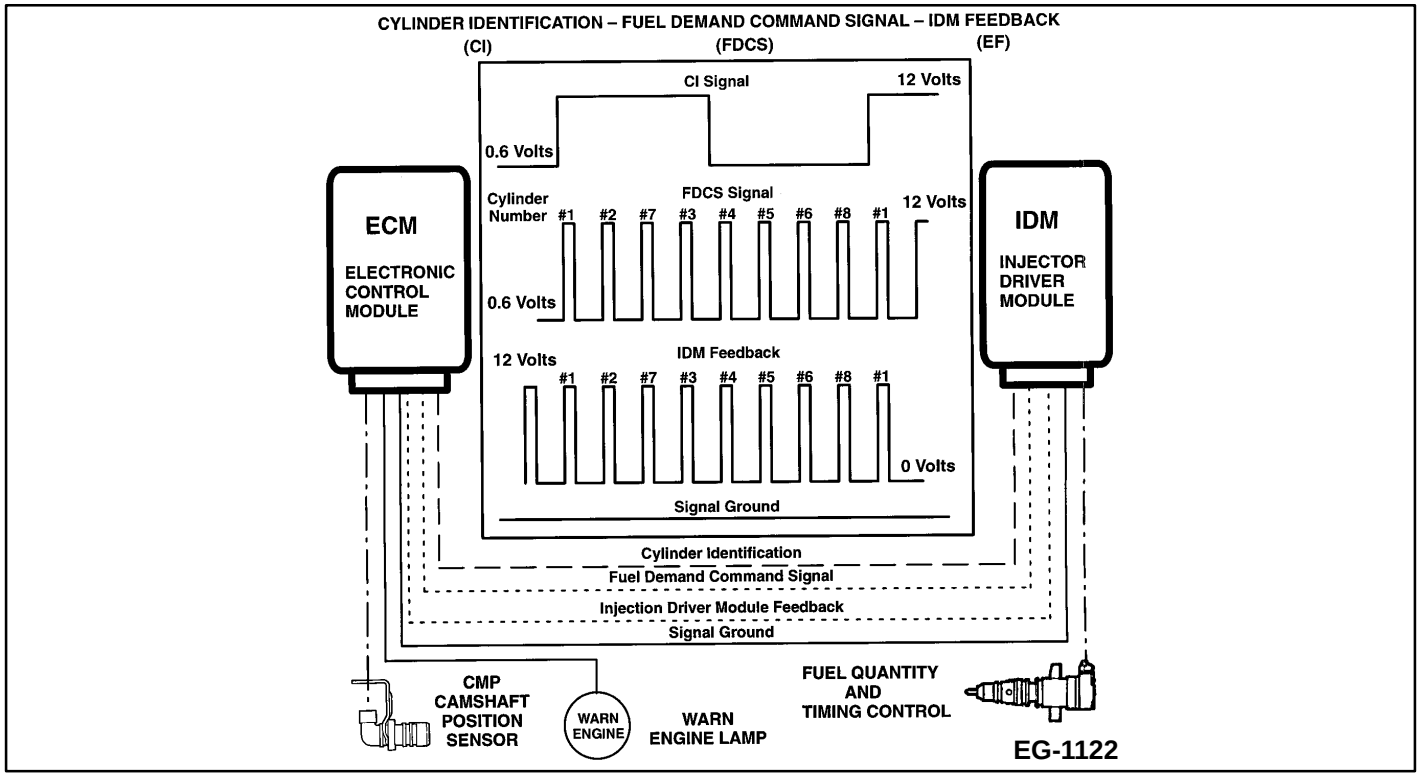
Flash Code *255*

ATA CODE SID 254 FMI 4

ECM: *OCC ORL*

If code 255 is present, replace the ECM.

ECM/IDM Communications (ECM/IDM)



SIGNAL FUNCTION

Cylinder Identification - Cylinder Identification (CI) signal is a 0 to12 volt wave form signal that communicates from the ECM to the IDM the position of cylinder 1. This signal is used by the IDM to synchronize the injector firing sequence. This signal is calculated from the signal generated from the Camshaft Position Sensor (CMP). The CI signal is generated by the ECM by “pulling down” (switching to grd.) a12 volt communication circuit in the IDM.

Fuel Demand Command Signal - Fuel Demand Command Signal is a 0 to12 volt wave form signal that communicates from the ECM to the IDM the required engine timing and duration of injector firing. The timing and duration of the signal is determined by ECM calibration and the signals of various sensor inputs. The FDCS signal is generated by the ECM by “pulling down” (switching to ground) a 12 volt communication circuit in the IDM.

Injector Driver Module Feedback - Injector Driver Module Feedback signal is a 0 to12 volt wave form signal that communicates from the IDM to the ECM a mirror image of the FDCS signal. Extensions of the EF (Electronic Feedback) signal can indicate to the ECM possible problems with the injectors by the IDM as the engine is running. An EF toggle (100 hz. signal) generated when the key is first turned “ON” and before the engine starts, communicates to the ECM that the IDM is powered up. In an engine off or engine running diagnostic mode, the EF signal is also used to communicate diagnostic information from the IDM to the ECM. The EF signal is generated by the IDM by “pulling down” (switching to grd) a12 volt communications circuit in the ECM.

FAULT DETECTION/MANAGEMENT

Cylinder Identification - Intermittent open or short to ground conditions can be detected by the IDM through IDM stuck high or low codes (532 & 531). Active faults can be detected by an on demand output circuit check performed during Engine Off Tests.

NOTE: *The engine will not operate without a functioning CI circuit*

Fuel Demand Command Signal - Active faults can be detected by an on demand output circuit check performed during Engine Off Tests.

NOTE: *The engine will not operate without a functioning FDCS circuit*

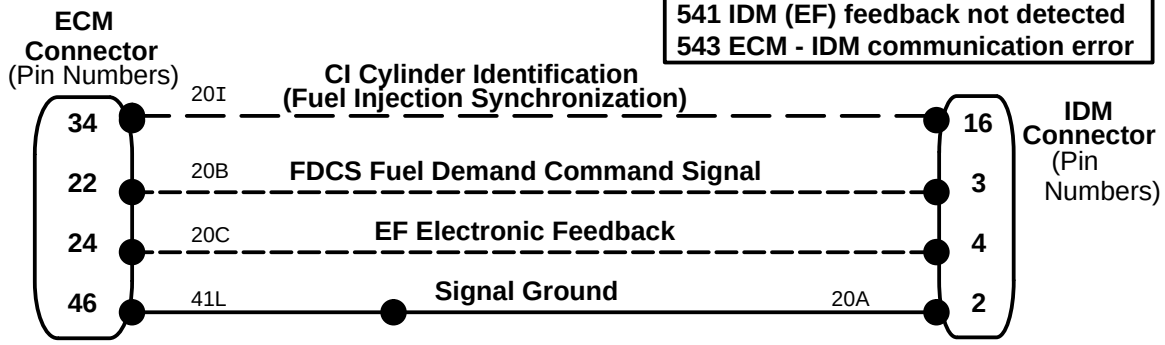
Injector Driver Module Feedback - Active faults can be detected by a toggle sequence that the ECM looks for on start up. The WARN lamp will be illuminated if this is detected.

NOTE: *IDM diagnostic fault codes will not be transmitted if the EF line is not functioning, however, the engine will operate normally.*

ECM/IDM Communications (ECM/IDM) Cont.

ECM - IDM COMMUNICATION
FDCS - Fuel Demand Command Signal
CI - Cylinder Identification
EF - IDM Feedback

Fault Codes:
242 FDCS output circuit check
253 CI output circuit check
531 CI signal stuck low
532 CI signal stuck high
541 IDM (EF) feedback not detected
543 ECM - IDM communication error



Key On Engine Off - Voltage Checks
(Check with breakout box installed with ignition key "ON" engine off).

Test Points	Spec.	Signal	Comments
#34 to #46	0.6 ± 0.1 v	CI signal	Less than .5v indicates an open between the ECM and IDM. 12 volts indicates an open in the ECM or breakout box.
#22 to #46	0.6 ± 0.1 v	FDCS signal	
#24 to #46	1 to 4 volts	EF feedback	With the key on, EF has a 100 hz. digital signal that will measure 1-4 volts w / DVOM.

Connector Checks to Ground
(Check with breakout box installed, ignition key should be in the OFF position.)

Test Points	Spec.	Signal	Comments
#34 to #46	> 1000 ohms	CI signal	Less than 1000 ohms indicates a short to ground either thru the harness or internal in the ECM or IDM. Disconnect the IDM and measure to ground. If short still present, disconnect the ECM and measure to ground. If short still present, repair harness.
#22 to #46	> 1000 ohms	FDCS signal	
#24 to #46	> 1000 ohms	EF feedback	

Harness Resistance Checks
(Check with breakout box installed, ignition key should be in the OFF position.)

Test Points	Spec.	Signal	Comments
#34 to #16	< 5 ohms	CI signal	Resistance from ECM connector to IDM connector.
#22 to #3	< 5 ohms	FDCS signal	Resistance from ECM connector to IDM connector.
#24 to #4	< 5 ohms	EF feedback	Resistance from ECM connector to IDM connector.
#46 to #2	< 5 ohms	SIG Grd	Resistance from ECM connector to IDM connector.

Key On Engine Running (at low idle) - Voltage Checks - Intermittent Faults
(Check with breakout box installed and engine at low idle.)

(Monitor suspect lines with voltmeter and wiggle appropriate wires and connectors while engine is idling)

Test Points	Spec.	Comments
#34 to #46	5 - 8 volts	CI signal (0 to12 volt digital signal), Monitor engine RPM w/Fluke 88 in TACH mode.
#22 to #46	1-1.5 volts	FDCS signal, 40 - 50hz. - 0 to 12 volt signal.
#24 to #46	.5 - 1.5 volts	EF signal, 40hz. - 0 to 12 volt signal.

Fault Code Descriptions

242 = FDCS high or low resistance in the circuit detected during engine off test, OCC***** test (REPAIR THIS FAULT FIRST).

253 = CI high or low resistance in the circuit detected during engine off test. OCC***** test (REPAIR THIS FAULT FIRST).

531 = CI signal stuck low, harness or internal circuits of IDM shorted to ground (intermittent problem, historical fault only)

532 = CI signal stuck high, harness or internal circuits of IDM shorted to voltage source (intermittent problem, historical fault only)

541 = IDM feedback (EF) (100 hz frequency transmitted during key ON, engine OFF) not detected.

543 = ECM-IDM communication error, no communication, detected on EF or wrong part number IDM.

*** - OCC = Output Circuit Check**

ECM/IDM Communications

EXTENDED SYSTEM DESCRIPTION - FUNCTION

The engine control system includes an Electronic Control Module (ECM) and an Injector Drive Module (IDM). The IDM's primary functions are to supply high current and voltage to power the injectors and to electrically "turn on" individual injectors upon command by the ECM. The ECM communicates and controls injector timing and fuel quantity and communicates engine position to the IDM to insure correct fueling timing, quantity and firing sequence. The IDM is also capable of feeding back or handshaking information received from the ECM and of communicating diagnostic information pertinent to injector or IDM operation to the ECM. Information is transmitted between the IDM and ECM on three circuits; (CI) Cylinder Identification, (FDCS) Fuel Demand Command Signal and (EF) Electronic Feedback.

Cylinder Identification (CI) is the signal from the ECM to the IDM to indicate the beginning of the firing order. This signal is generated by the ECM to indicate to the IDM the position of #1 cylinder and synchronize injector firing order to engine position. Engine position is detected by the Camshaft Position (CMP) sensor by identifying the sync window in the timing disk. (Refer to CMP sensor for complete function)

Fuel Demand Command Signal (FDCS) is the signal sent by the ECM to the IDM to indicate the beginning and ending of each injection cycle. This precise "On/Off" signal controls the fuel timing and rate by varying the beginning and ending of injection.

Electronic Feedback (EF) signal is sent from the IDM to the ECM to verify IDM operation and communicate diagnostic information.

- On initial power up, the IDM will signal the ECM with a constant 100 Hz signal that it has successfully initialized.
- During engine operation, the EF signal mirrors the FDCS signal to the ECM to verify FDCS reception by the IDM and will modify the EF signal if certain injector faults are detected during engine operation.
- After an "Engine Off Standard Test" is performed, the EF signal will communicate diagnostic information stored in the IDM pertaining to IDM function or injector operation to the ECM.

OPERATION

CYLINDER IDENTIFICATION (CI)

When the IDM is powered up, 12 volts is supplied from pin 16 of the IDM to pin 34 of the ECM. The ECM will "pull down" this 12 volts low to approximately .6 volts (the voltage drop across an internal transistor in the ECM). After the ECM has received a sync signal from the CMP sensor and can identify the position of cylinder #1, it will toggle CI and allow it to go high (12 volts), 180° of camshaft rotation later or 360° of crankshaft rotation the ECM will again pull the CI signal low (.6 volts). This indicates to the IDM to initiate the firing sequence when it receives the high signal and when it receives the low signal. This signal will be repeated every camshaft revolution.

FUEL DEMAND COMMAND SIGNAL (FDCS)

When the IDM is powered up,12 volts is also supplied from pin 12 of the IDM to pin 22 of the ECM, the ECM will "pull down" this 12 volts low to approximately .6 volts (the voltage drop across an internal transistor in the ECM). After the IDM has received the CI signal, the ECM will toggle the FDCS signal high and low to indicate to the IDM the beginning and ending of injector operation for each cylinder.

NOTE: *The engine requires a functioning CI and FDCS signal to operate.*

ELECTRONIC FEEDBACK (EF)

After the ignition key is turned "ON" and the ECM and IDM relays are enabled, the IDM is powered up and performs it's internal self checks. To signal that the IDM is initialized, a 100 Hz signal is transmitted on the EF circuit to the ECM.

During engine operation, the EF signal mirrors the FDCS signal to the ECM to verify FDCS reception by the IDM and will modify the EF signal if certain injector faults are detected during engine operation.

After an "Engine Off Standard Test" is performed, the EF signal will communicate diagnostic information stored in the IDM pertaining to IDM function or injector operation to the ECM.

ECM/IDM Communications

IDM DIAGNOSTICS

The IDM monitors operation of output circuits during engine operation. Output circuits that are shorted or open are detected by the IDM and are subsequently disabled if necessary to prevent damage to the output drivers. This will set a fault code. When a fault is detected during operation an EF "extension", transfers fault information to the ECM. Not all faults can be transferred during engine operation. However, faults are stored in the IDM when they are detected. These faults are transmitted during the "Engine Off Tests", as inactive faults.

At start up, the IDM performs a Self Test of internal components to determine if they are operating satisfactorily. The IDM compares the signal inputs to determine if the signal voltages are within specification, if not a fault code will be set. These faults are also transferred to the ECM on command as inactive faults.

ECM DIAGNOSTICS

The ECM monitors the timing of the EF signal while the engine is running. When it detects a fault sent from the IDM, it will log the transfer. However, it will be necessary to perform an Engine Off Standard Test to determine most fault codes stored in the IDM. The Engine Off Test may be initiated by the Electronic Service Tool or the STI Self Test Input switch located at the instrument panel.

The ECM continually measures the communication signal voltage levels. If the voltage levels are lower or higher than expected, a fault code will be set to identify the circuit or component. The fault will be automatically recorded as an active code. If the ignition key is turned off, the fault will be stored as an inactive code.

FLASH CODE *242*

ATA CODE SID 154 FMI 11

FDCS CIRCUIT TO IDM OCC SELF TEST FAILED

During the Engine Off Standard Output Circuit Check test, Code 242 will be set by the ECM, if the ECM did not detect a voltage transition on the FDCS circuit. This code will not cause the Engine Warning light to be illuminated.

Code 242 may be caused by a shorted high or low or open FDCS circuit. If accompanied by other communication codes could indicate the IDM is not powered up. This fault must be repaired for the engine to operate.

FLASH CODE *253*

ATA CODE SID 153 FMI 11

FUEL INJ. SYNC CIRCUIT OCC SELF TEST FAILED

Flash code 253 will be set during the Engine Off Standard Output Circuit Check test. This code is set by the ECM and indicates no voltage transition detected on the Cylinder Identification circuit. This fault will not cause the Engine Warning light to be illuminated.

Possible causes are a shorted (high or low) or open CI circuit. If accompanied by other communication codes could indicate the IDM is not powered up. This fault must be repaired for the engine to run.

FLASH CODE *531*

ATA CODE SID 153 FMI 4

FUEL INJ. SYNC SIGNAL LOW

Flash code 531 is set by the IDM and is transmitted to the ECM on command from the ECM during the Engine Off Standard Test. This code indicates that the IDM has detected that the FDCS signal and the CI signal have remained at 0 volts. This code will cause the Engine Warning light to be illuminated.

Possible cause may be a short to ground in the CI circuit. This fault must be repaired for the engine to run.

FLASH CODE *532*

ATA CODE SID 153 FMI 3

FUEL INJ. SYNC SIGNAL HIGH

Flash code 532 is set by the IDM and is transmitted to the ECM on command from the ECM during the Engine Off Standard Test. This code indicates the IDM has detected that the FDCS signal and CI signal have remained at 12 volts. This code will cause the Engine Warning light to be illuminated.

Possible causes are a short to a voltage source or an open CI circuit. This fault must be repaired for the engine to run.

ECM/IDM Communications

FLASH CODE *541*

ATA CODE SID 155 FMI 11

IDM FEEDBACK TOGGLE NOT DETECTED BY ECM

Flash code 541 is set by the ECM. The ECM monitors the CI, FDCS and EF signals for voltage levels. If the ECM detects that the CI or FDCS is open or if the EF signal is not sending a 100 Hz signal, this code will be set. This code will cause the Engine Warning light to be illuminated.

Possible causes are a short or open on the EF circuit if this code is the only code present. If accompanied by other IDM circuit faults the IDM may not be powered or operational. If displayed during an Engine Off Standard Test it will be accompanied by code 543. This code may be set due to other faults in the ECM due to a reset condition. If other codes are present repair them first in the order of importance for engine operation. This code should not prevent engine operation by itself.

FLASH CODE *543*

ATA CODE SID 155 FMI 7

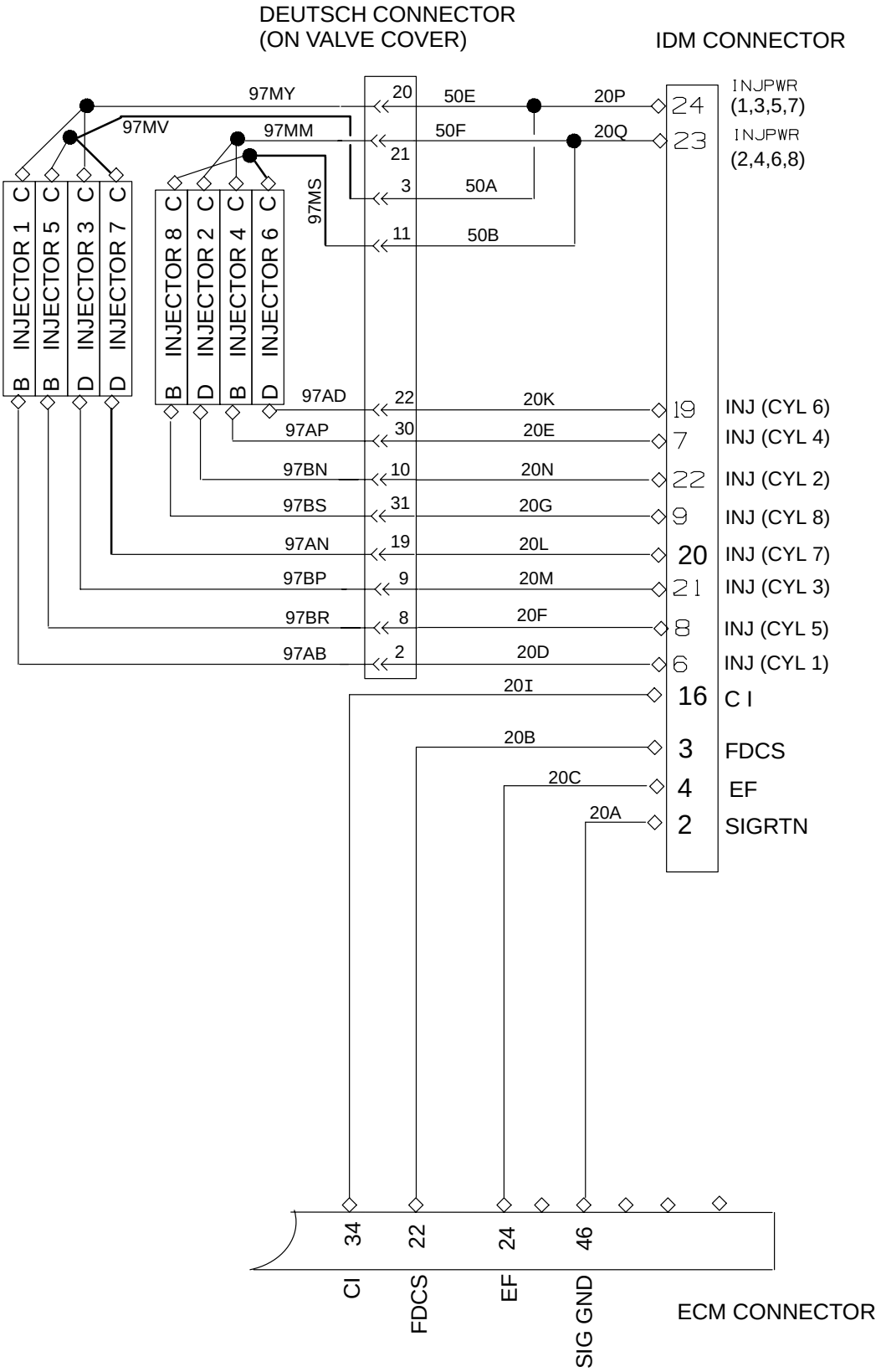
IDM FAULTS NOT RECEIVED

Flash code 543 is set by the ECM during an Engine Off Standard Output Circuit Check test. This indicates that the ECM has commanded the transmission of fault codes from the IDM and has not received the codes. If this code occurs, first record any active or inactive codes. Then clear the codes and rerun the Engine Off Standard Test. This code will cause the Engine Warning light to be illuminated.

Possible causes for this code would be opens or shorts in the IDM / ECM communications circuits or an IDM not powered. If accompanied by other faults repair the other faults first in the order of importance for engine operation. This code should not prevent engine operation by itself.

ECM/IDM Communications (ECM/IDM) Cont.

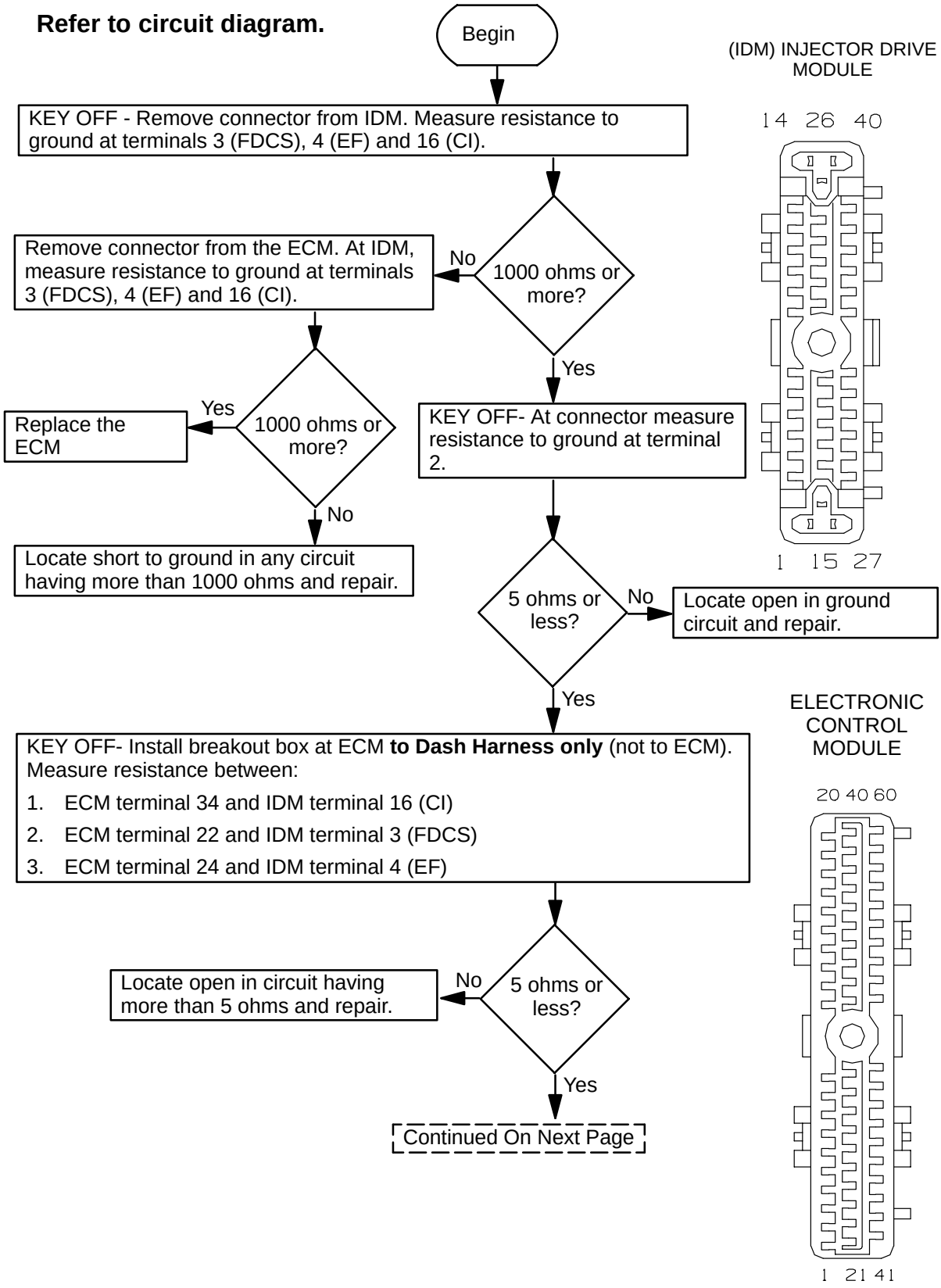
INJECTOR DRIVE CIRCUIT



ECM/IDM Communications (ECM/IDM) Cont.

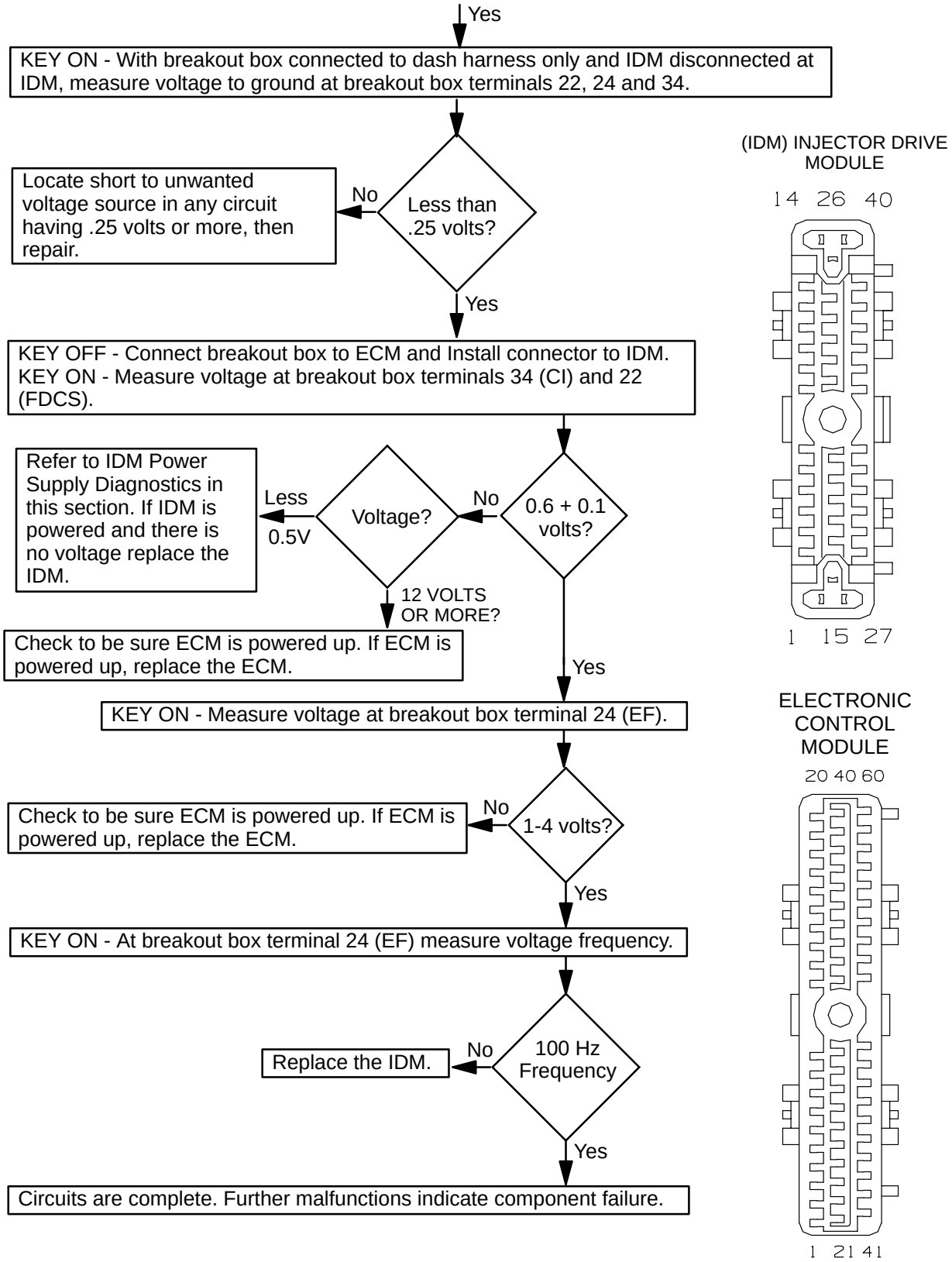
ECM ⇔ IDM COMMUNICATIONS (CONT.)

Refer to circuit diagram.

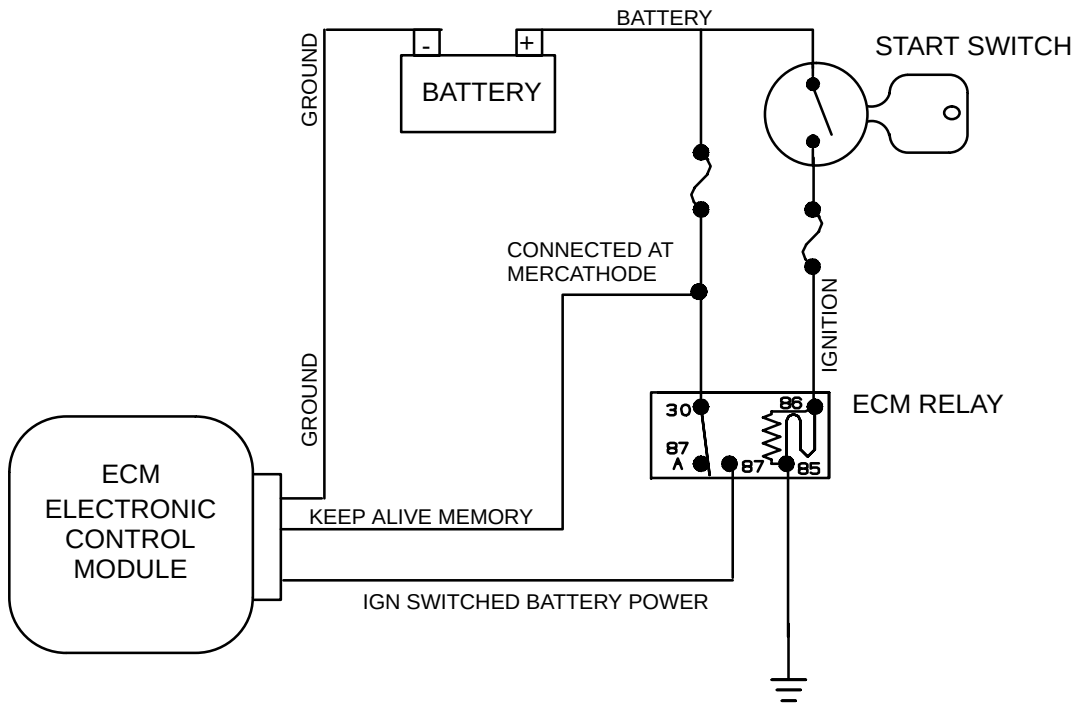

Begin
KEY OFF - Remove connector from IDM. Measure resistance to ground at terminals 3 (FDCS), 4 (EF) and 16 (CI).
1000 ohms or more?
No
Remove connector from the ECM. At IDM, measure resistance to ground at terminals 3 (FDCS), 4 (EF) and 16 (CI).
1000 ohms or more?
Yes
Replace the ECM
No
Locate short to ground in any circuit having more than 1000 ohms and repair.
Yes
KEY OFF- At connector measure resistance to ground at terminal 2.
5 ohms or less?
No
Locate open in ground circuit and repair.
Yes
KEY OFF- Install breakout box at ECM **to Dash Harness only** (not to ECM). Measure resistance between:
1. ECM terminal 34 and IDM terminal 16 (CI)
2. ECM terminal 22 and IDM terminal 3 (FDCS)
3. ECM terminal 24 and IDM terminal 4 (EF)
5 ohms or less?
No
Locate open in circuit having more than 5 ohms and repair.
Yes
Continued On Next Page
(IDM) INJECTOR DRIVE MODULE
14 26 40
1 15 27
ELECTRONIC CONTROL MODULE
20 40 60
1 21 41

ECM/IDM Communications (ECM/IDM) Cont.

ECM ⇔ IDM COMMUNICATIONS (CONT.)


Yes
KEY ON - With breakout box connected to dash harness only and IDM disconnected at IDM, measure voltage to ground at breakout box terminals 22, 24 and 34.
Less than .25 volts?
No
Locate short to unwanted voltage source in any circuit having .25 volts or more, then repair.
Yes
KEY OFF - Connect breakout box to ECM and Install connector to IDM. KEY ON - Measure voltage at breakout box terminals 34 (CI) and 22 (FDCS).
0.6 + 0.1 volts?
No
Voltage?
Less 0.5V
Refer to IDM Power Supply Diagnostics in this section. If IDM is powered and there is no voltage replace the IDM.
12 VOLTS OR MORE?
Check to be sure ECM is powered up. If ECM is powered up, replace the ECM.
Yes
KEY ON - Measure voltage at breakout box terminal 24 (EF).
1-4 volts?
No
Check to be sure ECM is powered up. If ECM is powered up, replace the ECM.
Yes
KEY ON - At breakout box terminal 24 (EF) measure voltage frequency.
100 Hz Frequency
No
Replace the IDM.
Yes
Circuits are complete. Further malfunctions indicate component failure.
(IDM) INJECTOR DRIVE MODULE
14 26 40
1 15 27
ELECTRONIC CONTROL MODULE
20 40 60
1 21 41

Electronic Control Module (ECM) Power Supply



ECM POWER SUPPLY

CIRCUIT FUNCTION

The ECM receives 12 volt operating power with the key ON from the ECM power relay. The ECM also receives 12 volt battery power at all times for the Keep Alive Memory function.

ECM SWITCHED POWER

Turning the key ON energizes the ECM power relay causing 12 volt battery power to be applied to ECM terminals 37 and 57.

ECM KEEP ALIVE MEMORY POWER

Battery power is applied at all times to support the ECMs keep alive memory. Refer to KEEP ALIVE MEMORY POWER CIRCUITS in this section for additional information.

ECM POWER GROUND

ECM terminals 40 and 60 are grounded through the chassis harness to the negative battery terminal.

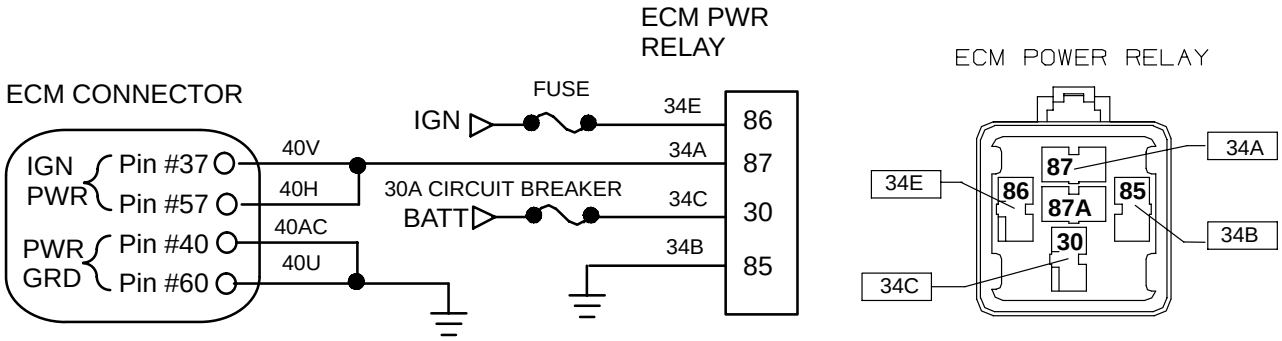
FAULT DETECTION MANAGEMENT

The ECM monitors voltage at terminals 37 and 57. If the ECM continuously receives less than 6.5 volts or more that 18 volts a fault code will be set. The fault codes do not cause the Warning light to be turned ON. If the condition is intermittent, the code will be logged as an inactive code.

Electronic Control Module (ECM) Power Supply (Cont.)

Electronic Control Module Power Supply (ECM-PWR)

Fault Codes:
112 Internal power out of range high
113 Internal power out of range low
224 KAM Corrupt



After removing connector always check for damaged pins, corrosion, loose terminals etc.

Relay Connector - Check connector with relay removed, ECM connector disconnected and key ON.

Test Points	Spec.	Comments
#30 to Grd.	12 ± 1.5 volts	< than 10.5 v check connections, 0 v check for open/short to ground or blown fuse
#86 to Grd.	12 ± 1.5 volts	< than 10.5 v check connections, 0 v check for open/short to ground or blown fuse
#86 to #85	12 ± 1.5 volts	< than 10.5 v check grd circuit connections, 0 v check for open ground circuit
#30 to #87	0 volts	Any voltage indicates a short to ground in ECM feed circuit

ECM Connector - Check with breakout box installed on engine harness only and with relay connector removed and key OFF.

Test Points	Spec.	Comments
#40 to Grd. #60 to Grd.	< 5 ohms	> 5 ohms indicates open or poor connection in ground circuits.
#37 to Grd. #57 to Grd.	>1000 ohms	< 1000 ohms indicates a short to ground

ECM Connector to Relay Connector - Check with breakout box installed on engine harness only and ECM Power Relay Connector with relay removed and key OFF.

Test Points	Spec.	Comments
#87 to 37 #87 to 57	<5 ohms	> 5 ohms indicates an open or poor connection. If <5 ohms the ECM power relay is suspect.

Fault Code Descriptions

112 = Internal power was more than 18 volts.
113 = Internal power was less than 6.5 volts.
224 = Keep Alive Memory in ECM lost.

Electronic Control Module (ECM) Power Supply (Cont.)

EXTENDED DESCRIPTION

Refer to the Electronic Control Module power supply circuit diagram for the following discussion.

The Electronic Control Module (ECM) Power Relay (395) has battery power supplied directly from the batteries to terminal 30. This circuit is protected by the 15A ECM #1 PWR fuse that is part of the battery cable assembly.

When the key switch is turned ON, the ECM Power Relay (395) is energized by ignition power from 5A fuse (5A fuse) at the relay control coil terminal 86. With the ECM Power Relay (395) energized, power flows through the normally open (N.O.) relay contacts (30 to 87) then on circuit 97AR to ECM connector (379), terminals 37 and 57.

The ground side of the ECM Power Relay control coil (terminal 85) is grounded by circuit 11-GK at the Electronic Ground Stud located at the cab. The Diode Assemby prevents the electronic components from voltage spikes created by the relay opening and closing.

The ECM power ground terminals 40 and 60 are grounded through ECM connector at the negative battery terminal.

ECM DIAGNOSTICS

If the ECM continuously receives less than 6.5 volts or more than 18 volts at terminals 37 and 57, it will cause Flash Code 112 or 113 to be set.

FLASH CODE *112*

ATA CODE PID 168 FMI 3

ECM: *INTERNAL VOLTAGE POWER OUT OF RANGE HIGH*

Code 112 can be caused by either of two conditions:

1. Vehicle voltage supply to the ECM is continuously more than 18 volts. Excessive voltage can be caused by a defective alternator.
2. The ECM has an internal fault.

If the condition causing code 112 is intermittent, the code will change from active to inactive status. Code 112 does not cause the Engine Warning light to turn ON.

FLASH CODE *113*

ATA CODE PID 168 FMI 4

ECM: *INTERNAL VOLTAGE POWER OUT OF RANGE LOW*

Code 113 can be caused by consistently less than 6.5 volts being applied to ECM terminals 37 and 57. This can be caused by a defective alternator, low batteries, and/or increased resistance in the battery feed circuits. Code 113 does not turn the Engine Warning Light ON. If the condition causing Code 113 to set is an intermittent condition, when the condition is no longer present, the code status will change from active to inactive.

Flash Code *224*

ATA CODE SID 254 FMI 2

ECM: *KAM Corrupt*

Flash code 224 can be caused by high or low battery power supply to ECM terminal 1 OR an internal ECM error.

TROUBLESHOOTING

If Flash Code 112 is active, refer to CTS- 5000 Master Service Manual, GROUP 08 - ALTERNATORS and troubleshoot the charging system.

If Flash Code 113 is active or NO voltage is present to the ECM, perform TESTING ECM POWER SUPPLY CIRCUITS. If the power supply to the ECM checks good, replace the ECM.

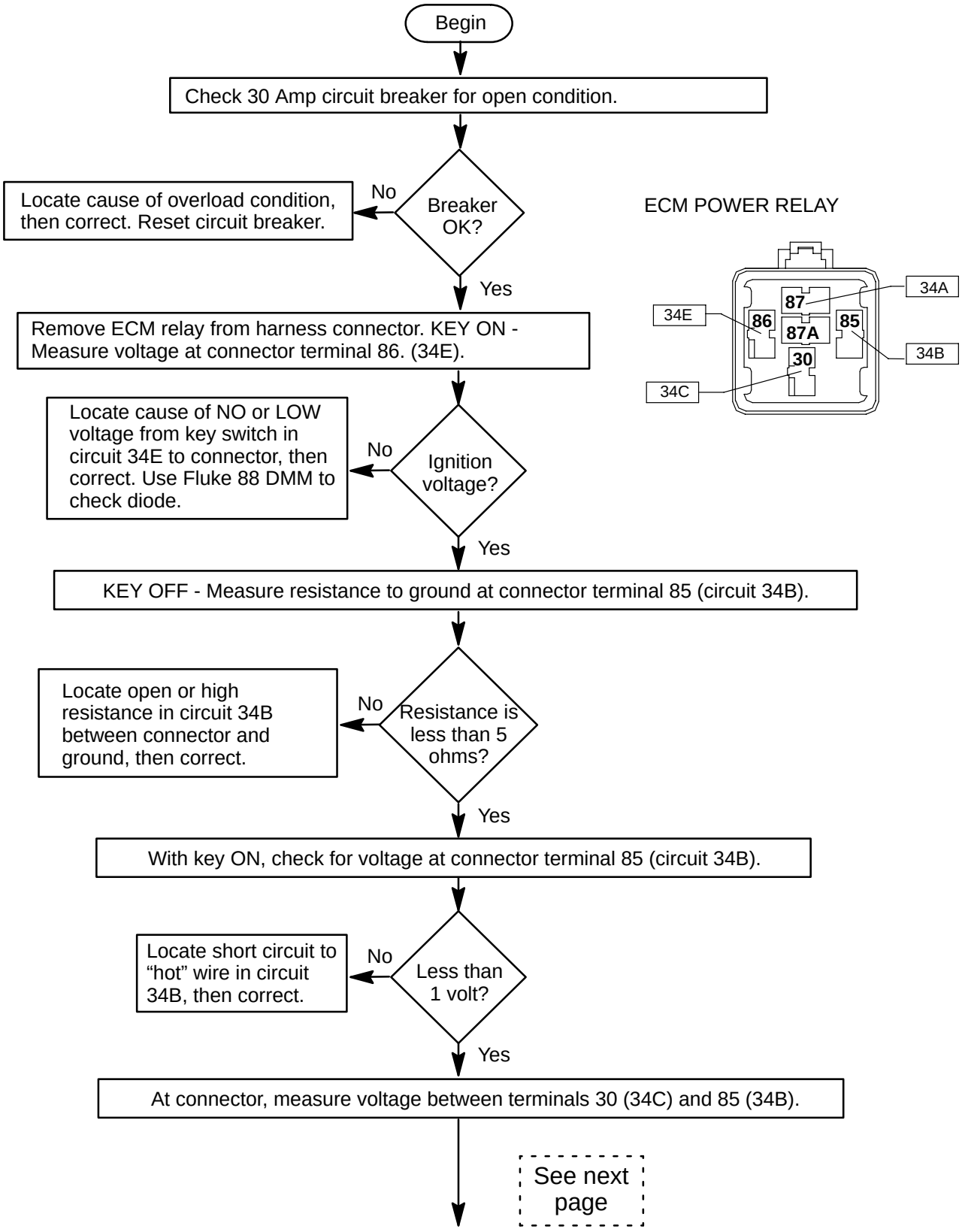
If a vehicle no-start condition is present and there is no power to the ECM, perform TESTING ECM POWER SUPPLY CIRCUITS.

BEFORE PERFORMING ANY TESTS

Inspect ECM power relay circuit connectors for pushed back, damaged, corroded or dirty terminals as well as making sure the terminals and wires are properly crimped. Make sure connectors are properly joined together. Also check for damaged wiring, and clean, tight battery and ground connections.

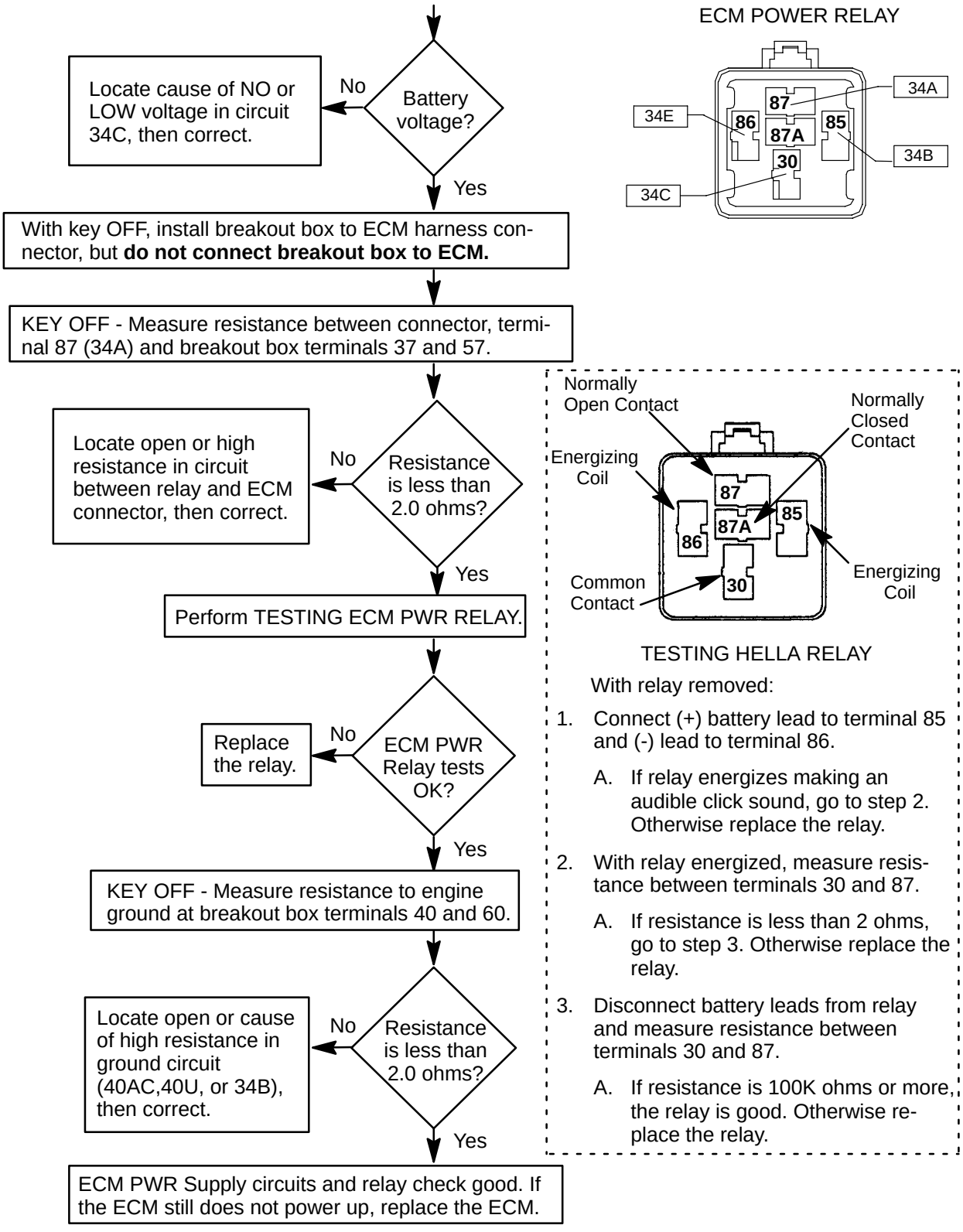
Electronic Control Module (ECM) Power Supply (Cont.)

TESTING ECM POWER SUPPLY CIRCUIT


Begin
Check 30 Amp circuit breaker for open condition.
Breaker OK?
No
Locate cause of overload condition, then correct. Reset circuit breaker.
Yes
Remove ECM relay from harness connector. KEY ON - Measure voltage at connector terminal 86. (34E).
Ignition voltage?
No
Locate cause of NO or LOW voltage from key switch in circuit 34E to connector, then correct. Use Fluke 88 DMM to check diode.
Yes
KEY OFF - Measure resistance to ground at connector terminal 85 (circuit 34B).
Resistance is less than 5 ohms?
No
Locate open or high resistance in circuit 34B between connector and ground, then correct.
Yes
With key ON, check for voltage at connector terminal 85 (circuit 34B).
Less than 1 volt?
No
Locate short circuit to “hot” wire in circuit 34B, then correct.
Yes
At connector, measure voltage between terminals 30 (34C) and 85 (34B).
See next page
ECM POWER RELAY
34A
34E
87
86
87A
85
30
34B
34C

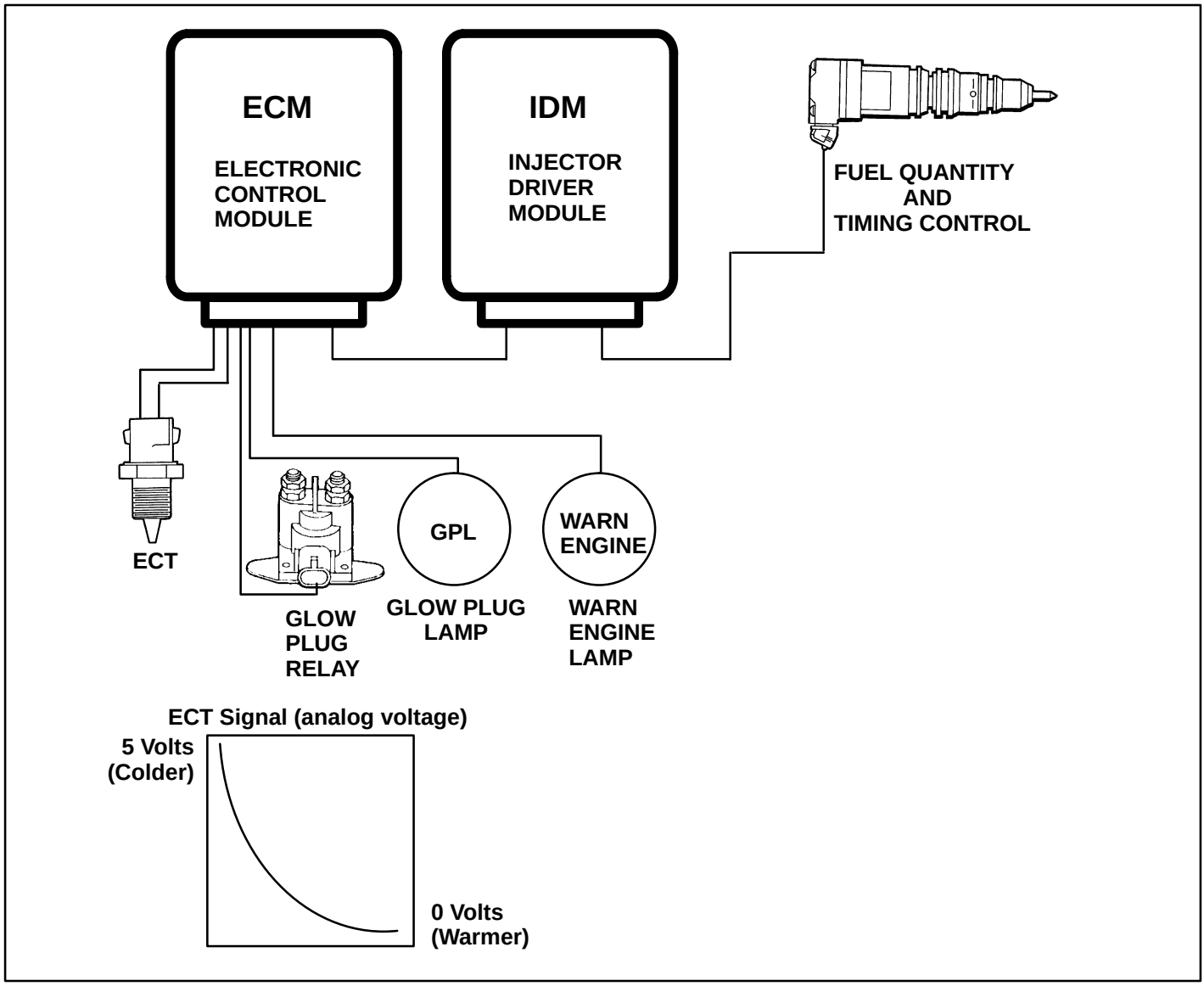
Electronic Control Module (ECM) Power Supply (Cont.)

TESTING ECM POWER SUPPLY CIRCUIT (CONT.)


Battery voltage?
No
Locate cause of NO or LOW voltage in circuit 34C, then correct.
Yes
With key OFF, install breakout box to ECM harness connector, but **do not connect breakout box to ECM.**
KEY OFF - Measure resistance between connector, terminal 87 (34A) and breakout box terminals 37 and 57.
Resistance is less than 2.0 ohms?
No
Locate open or high resistance in circuit between relay and ECM connector, then correct.
Yes
Perform TESTING ECM PWR RELAY.
ECM PWR Relay tests OK?
No
Replace the relay.
Yes
KEY OFF - Measure resistance to engine ground at breakout box terminals 40 and 60.
Resistance is less than 2.0 ohms?
No
Locate open or cause of high resistance in ground circuit (40AC,40U, or 34B), then correct.
Yes
ECM PWR Supply circuits and relay check good. If the ECM still does not power up, replace the ECM.
ECM POWER RELAY
34A
34E
87
86
87A
85
30
34B
34C
Normally Open Contact
Normally Closed Contact
Energizing Coil
87
87A
85
86
30
Common Contact
Energizing Coil
TESTING HELLA RELAY
With relay removed:
1. Connect (+) battery lead to terminal 85 and (-) lead to terminal 86.
A. If relay energizes making an audible click sound, go to step 2. Otherwise replace the relay.
2. With relay energized, measure resistance between terminals 30 and 87.
A. If resistance is less than 2 ohms, go to step 3. Otherwise replace the relay.
3. Disconnect battery leads from relay and measure resistance between terminals 30 and 87.
A. If resistance is 100K ohms or more, the relay is good. Otherwise replace the relay.

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Engine Coolant Temperature (ECT) Sensor



SIGNAL FUNCTION

The Engine Coolant Temperature (ECT) sensor is a thermistor type sensor that has a variable resistance that changes when exposed to different temperatures. When interfaced with the ECM it produces a 0 to 5 volt analog signal that will measure temperature.

Coolant Temperature Compensation - At coolant temperatures greater than 214°F (101° C) fuel quantity is reduced by 6% for each degree of temperature (°C), until engine temperature reaches 218° F (103°C) . Above 218° F (103°C) fuel is reduced by 3% for each °C increase in temperature.

Idle Speed - At temperatures below 158° F, (70° C) low idle is incrementally increased to a maximum of 875 RPM.

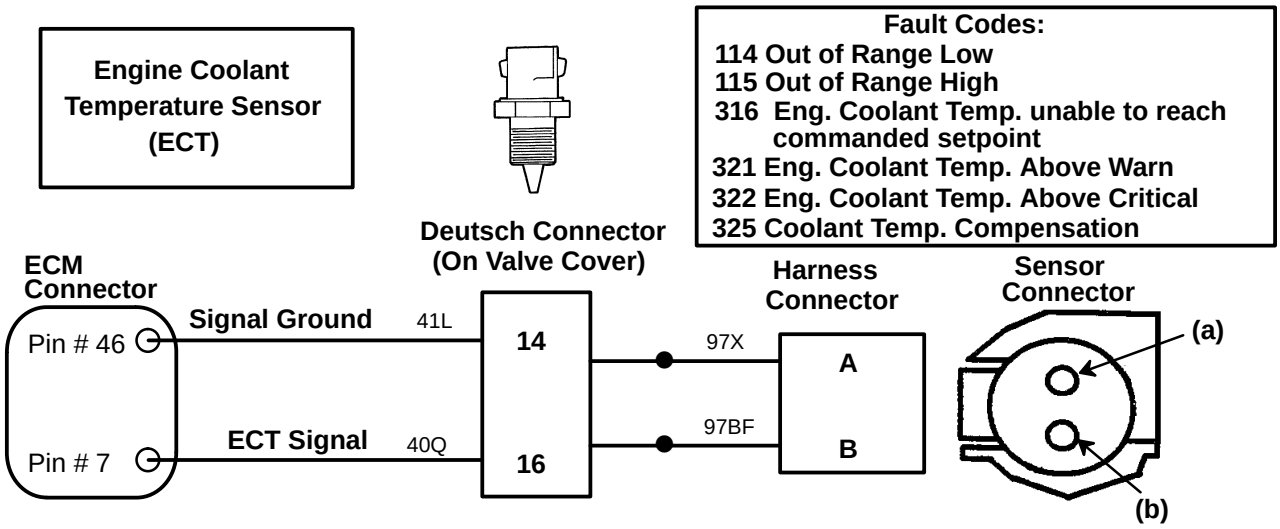
Glow Plug Control - Glow plug relay and lamp on times are directly affected by engine coolant temperature.

Engine Warning and Protection - Optional feature when enabled, will warn driver of overheat condition and can be programmed to shut the engine down.

FAULT DETECTION/MANAGEMENT

An ECT signal that is detected out of range high or low by the ECM will cause the ECM to ignore the ECT signal and assume an engine coolant temperature of -29°F (-20°C) for starting and a temperature of 180° F (82° C) for engine running conditions. The WARN lamp will also be illuminated as long as the fault condition exists.

Engine Coolant Temperature (ECT) Sensor (Cont.)



After removing connectors always check for damaged pins, corrosion, loose terminals etc.

Connector Checks to Ground
(Check with Sensor Connector Disconnected and Ignition key off, all accessories off)

Test Points	Spec.	Comments
A to Grd.	< 5 ohms	Resistance to ground, check with key OFF, if > 5 ohms the harness is open.
B to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.

Connector Voltage Checks
(Check with sensor Connector Disconnected and Ignition Key On)

Test Points	Spec.	Comments
B to Grd.	4.6 - 5.0 v	Pull up voltage, if no or low voltage, circuit has open or high resistance or short to Grd.
A to Grd.	0 - .25 v	If greater than .25 volts, wire is shorted to V Ref. or battery

Harness Resistance Checks
(Check with breakout box installed on engine harness only)

Test Points	Spec.	Comments
#46 to A	< 5 ohms	Resistance from harness connector to 60 pin connector - Signal ground
#7 to B	< 5 ohms	Resistance from harness connector to 60 pin connector - ECT Signal

Operational Signal Checks
(Check with breakout box installed in line with the ECM)

Test Points (+) #7 to (-) #46				
Voltage	Temp. ° F	Temp. ° C	Resistance	Comments
0.53 v	248	120	1.19 K ohms	
0.96 v	212	100	2 K ohms	
1.37 v	176	80	3.84 K ohms	
4.37 v	32	0	69.2 K ohms	
4.60 v	-5	-20	131.0 K ohms	

Fault Code Descriptions

Circuit Faults:

114 = Signal was less than .127 volts for more than 0.1 seconds. (Probable short to ground.)

115 = Signal voltage was greater than 4.8 volts for more than 0.1 seconds. (Probable open circuit.)

Cooling System Faults:

316 = Coolant temp. has not reached 41°F

321 = Engine Coolant Temperature above WARN level 225° F (107° C)

322 = Engine Coolant Temperature above Critical level 234° F (112.5°C)

325 = Coolant Temperature Compensation enabled,
(Reduces fuel quantity 6% for each degree °C above 214° F (101°C)

Engine Coolant Temperature (ECT) Sensor (Cont.)

FUNCTION

The engine control system includes an Engine Coolant Temperature sensor. The ECM measures the Engine Coolant Temperature signal and uses this information for Coolant Temperature Compensation and optional high temperature warning and shut down systems.

Coolant temperature compensation is used to protect the engine if the coolant temperature is too high. The ECM monitors the ECT signal to determine the coolant temperature. If the coolant reaches 214°F (101°C), the ECM will reduce the fuel delivery by 6% for each Celsius degree of temperature increase. If the coolant temperature increases to 218°F (104°C), fuel quantity will be reduced 3% for each Celsius degree of temperature increase. Coolant Temperature Compensation can be programmed to be inoperative in certain applications where full engine performance is required over the protection of the engine.

On engines equipped with an engine warning system, the ECM will activate the audible warning alarm and illuminate the red Oil/Water warning light when the engine coolant temperature reaches 225°F (107°C).

OPERATION

The Engine Coolant Temperature Sensor is a thermistor type sensor which changes resistance when exposed to different temperatures.

When the temperature of the coolant is decreased, the resistance of the thermistor increases which causes the signal voltage to increase. As the temperature of the coolant is increased the resistance of the thermistor decreases, which causes the signal voltage to decrease.

The ECT sensor is supplied a regulated 5 volt reference voltage from ECM terminal 7. The sensor is grounded at terminal A through the signal return, terminal 46, at the ECM. As the coolant temperature increases or decreases, the sensor changes resistance and provides the ECM with the coolant temperature signal voltage at terminal 7 of the ECM. This signal voltage is then read by the ECM to determine the temperature of the coolant.

ECM DIAGNOSTICS

With the ignition key “ON”, the ECM continuously monitors the ECT circuit for expected voltages. If the signal voltage is less than or more than expected the ECM will set a fault code.

If the ECM detects a fault in the ECT signal, the ECM will disregard the signal and default to a temperature of 180°F (82°C) for engine running operation and -4°F (-20°C) for starting the engine. If the fault is no longer present, the ECM will once again return to normal operation using the ECT signal for processing.

Faults in the ECT signal can be retrieved using the Self Test Input Switch (STI) or the Electronic Service Tool. If the fault is no longer present, it will be stored as an Inactive Code.

FLASH CODE *114*

ATA CODE PID 110 FMI 4

ECT: *OUT OF RANGE LOW*

An out of range low code will be set if the ECM detects a voltage less than .127 volts for more than 0.1 seconds. If this fault is Active, the ECM will use the default value of 180°F (82°C).

Code 114 may be caused by a short to ground or a shorted or biased sensor.

FLASH CODE *115*

ATA CODE PID 110 FMI 3

ECT: *OUT OF RANGE HIGH*

An out of range high code will be set if the ECM detects a voltage greater than 4.6 volts for more than 0.1 seconds. If this fault is Active, the ECM will use the a default value of 180°F (82°C).

Code 115 may be caused by an open circuit, an open sensor, or a short to another voltage source.

Engine Coolant Temperature (ECT) Sensor (Cont.)

FLASH CODE *316*

ATA CODE PID 110 FMI 1

ENGINE COOLANT TEMPERATURE UNABLE TO REACH COMMANDED SETPOINT

Code 316 will only be set with engines that have the Cold Ambient Protection (CAP) System enabled. This code will be set after the engine has run for greater than 120 minutes and has not exceeded 147°F (75°C) for vehicles with manual transmissions and 140°F (60°C) for vehicles with automatic transmissions.

NOTE: *This code only indicates that the engine has not been able to reach operating temperature. It does not indicate an electronic fault.*

Possible causes of code 316: Extended idle time, cold ambient temperatures, (may require use of winter front), thermostat stuck open, and mis-plumbed cooling system (thermostat bypass bypassed).

FLASH CODE *321*

ATA CODE PID 110 FMI 0

ENGINE COOLANT TEMPERATURE ABOVE WARNING LEVEL

Code 321 will be set if the ECM detects engine coolant temperature above 225°F (107°C). When this occurs, the ECM illuminates the OIL/WATER warning light and sounds the audible alarm (if equipped), alerting the operator that a potential for engine damage exists.

If the temperature drops below 225°F(107°C), the code will become inactive and the ECM will return to normal operation.

FLASH CODE *322*

ATA CODE PID 110 FMI 7

ENGINE COOLANT TEMPERATURE ABOVE CRITICAL LEVEL

Code 322 will be set if the ECM detects engine coolant temperature above 235°F (112.5°C). When this occurs, the OIL/WATER warning light illuminates and the audible alarm sounds (if equipped) will alert the operator that the temperature is increasing (having set code 321) indicating a potential for engine damage. With code 322 active, the engine will shut down. At the same time the code and current engine hours will be recorded in the VPM as an Engine Event.

If the temperature drops below 235°F (112.5°C), the code will become inactive and the ECM will return to normal operation. Should the engine shut down, it can be restarted to move the vehicle to a safe place.

FLASH CODE *325*

ATA CODE PID 110 FMI 14

POWER REDUCED, MATCHED TO COOLING SYSTEM PERFORMANCE

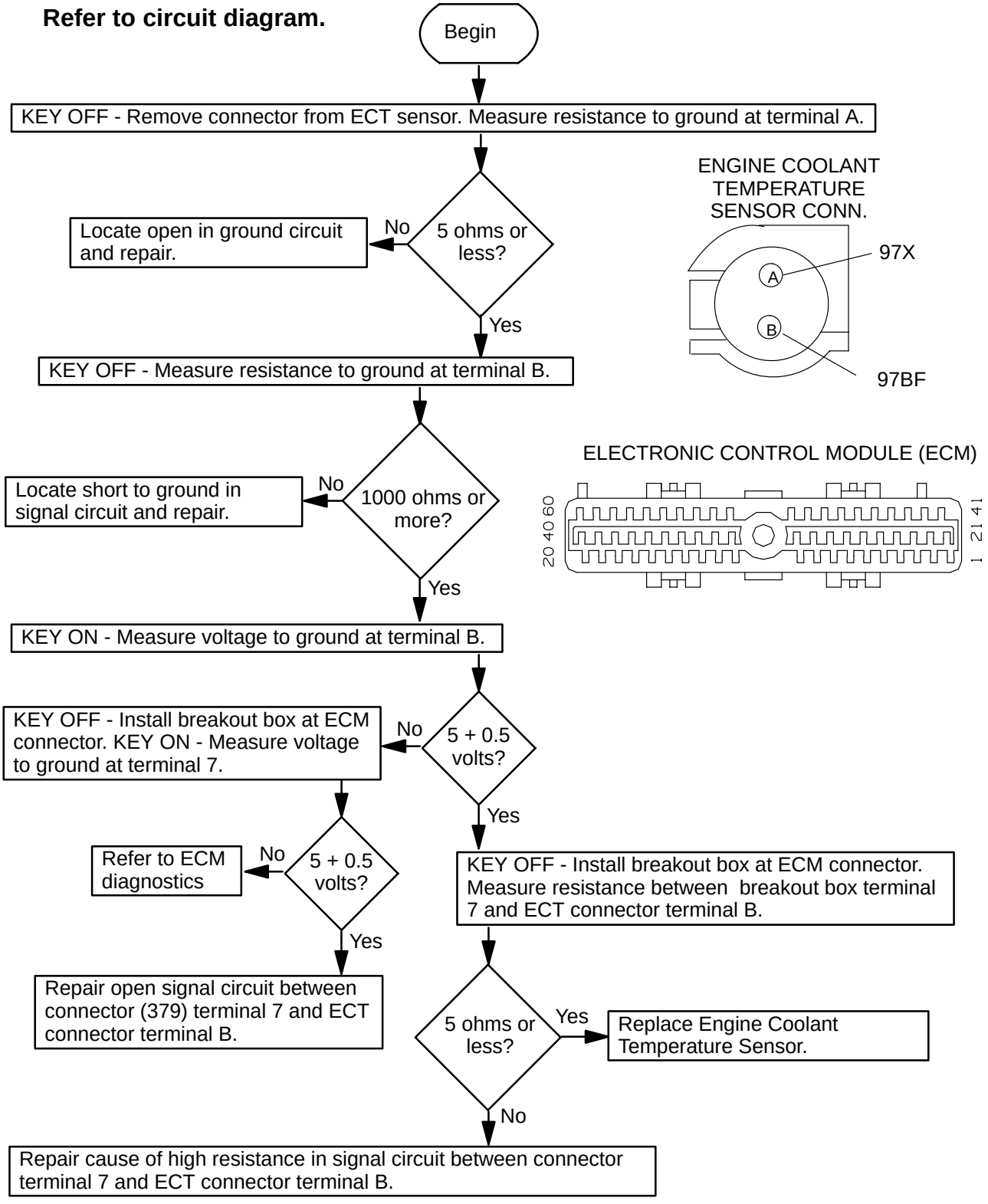
Code 325 will be set if the cooling system temperature exceeds 214°F (101°C). At this temperature the ECM will reduce the fuel delivered to the engine at or near the maximum demand level. For each one Celsius degree of temperature the fuel will be reduced 6%. This reduces the heat produced by the engine thereby reducing the burden on the engine cooling system.

As the temperature is reduced the compensation level is reduced until the temperature drops below 214°F (101°C) at which normal operation is resumed.

Engine Coolant Temperature (ECT) Sensor (Cont.)

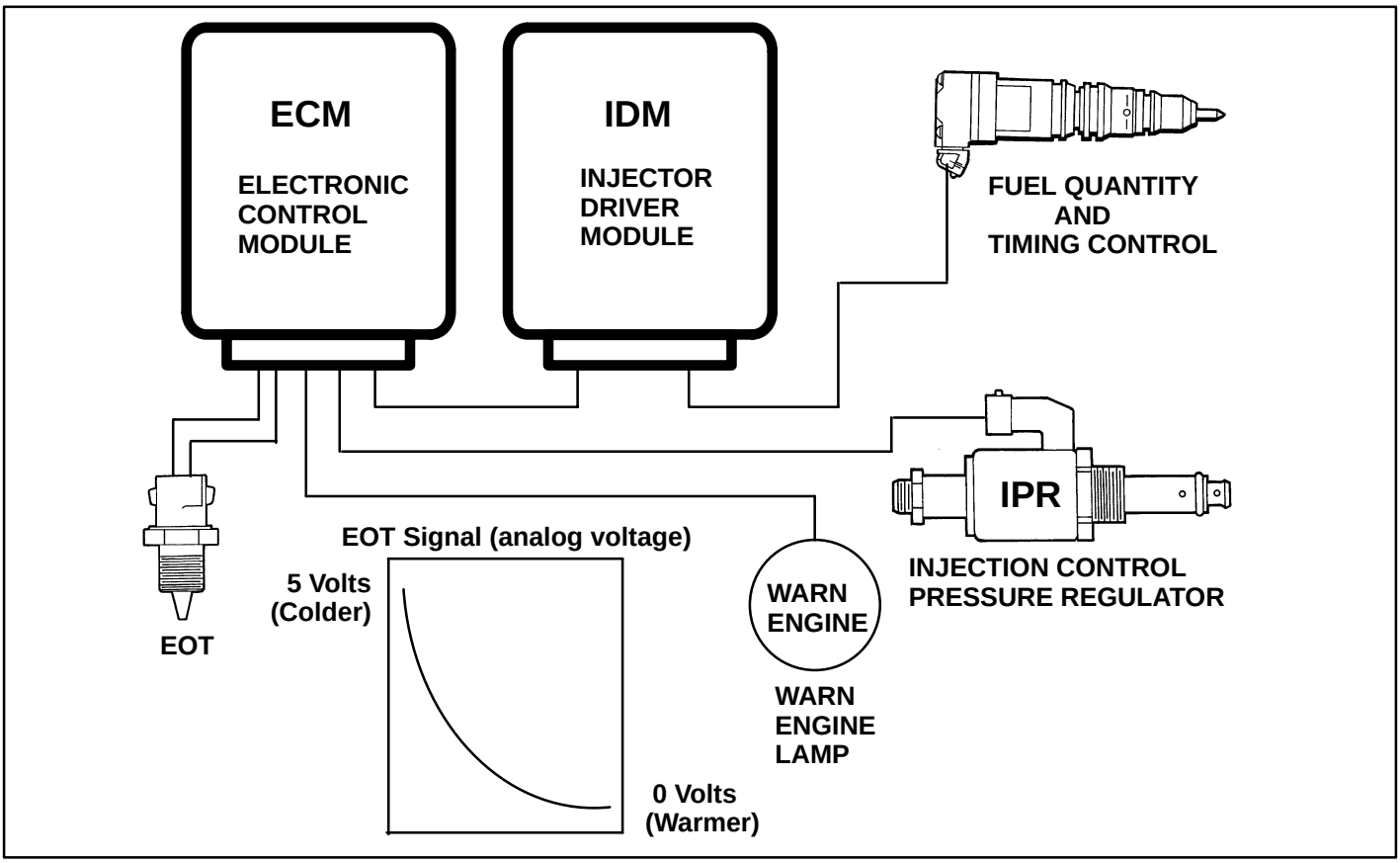
SENSOR DIAGNOSTICS

Refer to circuit diagram.


Begin
KEY OFF - Remove connector from ECT sensor. Measure resistance to ground at terminal A.
5 ohms or less?
No
Locate open in ground circuit and repair.
Yes
KEY OFF - Measure resistance to ground at terminal B.
1000 ohms or more?
No
Locate short to ground in signal circuit and repair.
Yes
KEY ON - Measure voltage to ground at terminal B.
5 + 0.5 volts?
No
KEY OFF - Install breakout box at ECM connector. KEY ON - Measure voltage to ground at terminal 7.
Yes
5 + 0.5 volts?
No
Refer to ECM diagnostics
Yes
Repair open signal circuit between connector (379) terminal 7 and ECT connector terminal B.
KEY OFF - Install breakout box at ECM connector. Measure resistance between breakout box terminal 7 and ECT connector terminal B.
5 ohms or less?
Yes
Replace Engine Coolant Temperature Sensor.
No
Repair cause of high resistance in signal circuit between connector terminal 7 and ECT connector terminal B.
ENGINE COOLANT TEMPERATURE SENSOR CONN.
97X
A
B
97BF
ELECTRONIC CONTROL MODULE (ECM)
20 40 60
1 21 41

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Engine Oil Temperature (EOT) Sensor



SIGNAL FUNCTIONS

The Engine Oil Temperature (EOT) sensor is a thermistor type sensor that has a variable resistance which changes when exposed to different temperatures. When interfaced with the ECM, it produces a 0 to 5 volt analog signal that indicates temperature.

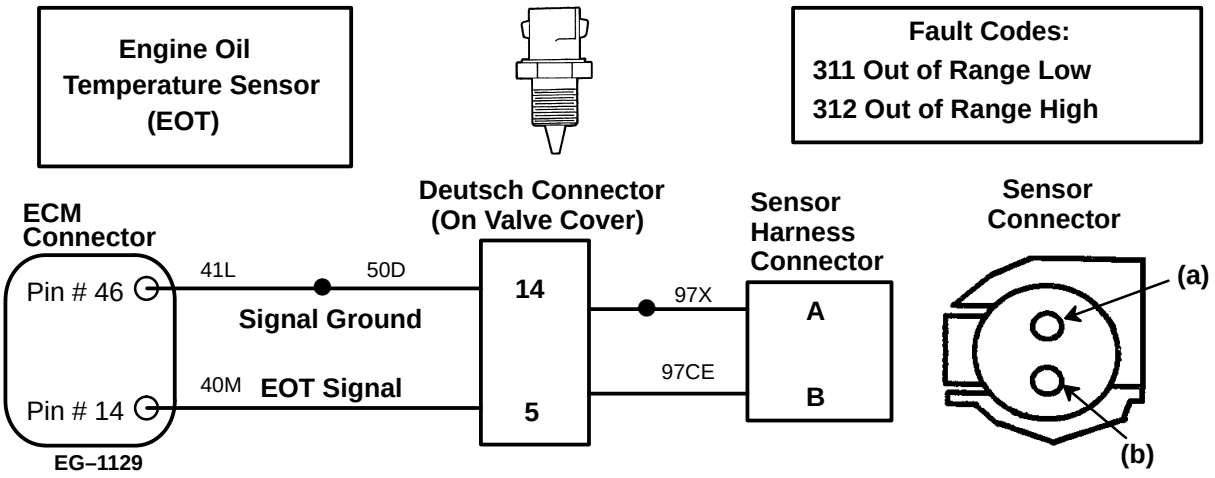
Cranking Fuel Quantity/Timing Control – The EOT signal is used to determine the timing and quantity of fuel required to optimize starting over all temperature conditions.

Temperature Compensation – Fuel quantity and timing is controlled throughout the total operating range to compensate for oil viscosity changes due to temperature variations and insure that adequate torque and power is available.

FAULT DETECTION/MANAGEMENT

An EOT signal that is detected out of range high or low by the ECM will cause the ECM to ignore the EOT signal and default to the engine coolant temperature (ECT) sensor. The WARN engine lamp will also be illuminated as long as the fault condition exists. If both the EOT and ECT sensors are not functioning, the ECM will assume a 212°F (100°C) value for engine oil temperature.

Engine Oil Temperature (EOT) Sensor (Cont.)



After removing connectors always check for damaged pins, corrosion, loose terminals etc.

Connector Checks to Ground
(Check with Sensor Connector Disconnected and Ignition key off, all accessories off)

Test Points	Spec.	Comments
A to Grd.	< 5 ohms	Resistance to ground, check with key OFF, if > 5 ohms the harness is open.
B to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.

Connector Voltage Checks
(Check with sensor Connector Disconnected and Ignition Key On)

Test Points	Spec.	Comments
B to Grd.	4.8 – 5.0v	Pull up voltage, if no or low voltage, circuit has open or high resistance or short ground.
A to Grd.	0 – .25v	If greater than .25 volts, signal ground wire is shorted to V Ref. or battery

Harness Resistance Checks
(Check with breakout box installed on engine harness only)

Test Points	Spec.	Comments
#46 to A	< 5 ohms	Resistance from harness connector to 60 pin connector – Signal ground
#14 to B	< 5 ohms	Resistance from harness connector to 60 pin connector – EOT Signal

Operational Voltage Checks
(Check with breakout box installed in line with the ECM)

Test Points (+) #14 to (–) #46				
Voltage	Temp. ° F	Temp. ° C	Resistance	Comments
0.53 v	248	120	1.19 K ohms	
0.96 v	205	96	2 K ohms	
1.37 v	176	80	3.84 K ohms	
4.37 v	32	0	69.2 K ohms	
4.60 v	–5	–20	131.0 K ohms	

Fault Code Descriptions

Circuit Faults:

311 = Signal was less than 0.2 volts for more than 0.1 seconds.

312 = Signal voltage was greater than 4.8 volts for more than 0.1 seconds.

Engine Oil Temperature (EOT) Sensor (Cont.)

FUNCTION

The engine control system includes an Engine Oil Temperature (EOT) sensor. The ECM monitors engine oil temperature via the EOT sensor signal to control fuel quantity and timing throughout the operating range of the engine. The EOT signal allows the ECM to compensate for oil viscosity variations due to temperature changes in the operating environment. This insures that adequate power and torque are available under all operating conditions.

OPERATION

The Engine Oil Temperature Sensor is a thermistor type sensor which changes resistance when exposed to different oil temperatures.

When the temperature of the oil is decreased the resistance of the thermistor increases which causes the signal voltage to increase. As the temperature of the oil is increased, the resistance of the thermistor decreases, causing the signal voltage to decrease.

The EOT sensor is supplied a regulated 5 volt reference signal at terminal B from ECM terminal 14. A return circuit (ground) is supplied at terminal A from ECM terminal 46. As the oil temperature increases or decreases, the sensor changes resistance and provides the ECM with the oil temperature signal voltage at terminal 14. This signal voltage is then read by the ECM to determine the temperature of the oil.

ECM DIAGNOSTICS

With the ignition key “ON”, the ECM continuously monitors the EOT signal to determine if it is within expected values. If the signal voltage is above or below the expected levels, the ECM will set a fault code.

If the ECM detects a fault, it will use the value of the Engine Coolant Temperature signal, in place of the EOT signal. If the ECT sensor is not sending a correct signal, the ECM will default to -4°F (-20°C) for starting or 212°F (100°C) for engine running operation.

EOT sensor faults can be retrieved using the Electronic Service Tool or by reading the flash codes from the warning light using the STI diagnostic switch located on the vehicle dash. If the ignition key is shut off, the code will become an Inactive code. EOT codes will cause the Engine Warning light to be illuminated.

FLASH CODE *311*
ATA CODE PID 175 FMI 4
ENGINE OIL TEMPERATURE SIGNAL OUT OF RANGE LOW

Code 311 out of range low, will be set if the signal voltage was less than 0.2 volts for more than 0.1 seconds. If this code is set, the ECM will default to ECT temperature or a default value of -4°F (-20°C) for starting or 212°F (100°C) for engine running operation. This code will cause the ECM to illuminate the Engine Warning light.

Code 311 may be set due to a short to ground in the signal circuit or a defective sensor.

FLASH CODE *312*
ATA CODE PID 175 FMI 3
ENGINE OIL TEMPERATURE SIGNAL OUT OF RANGE HIGH

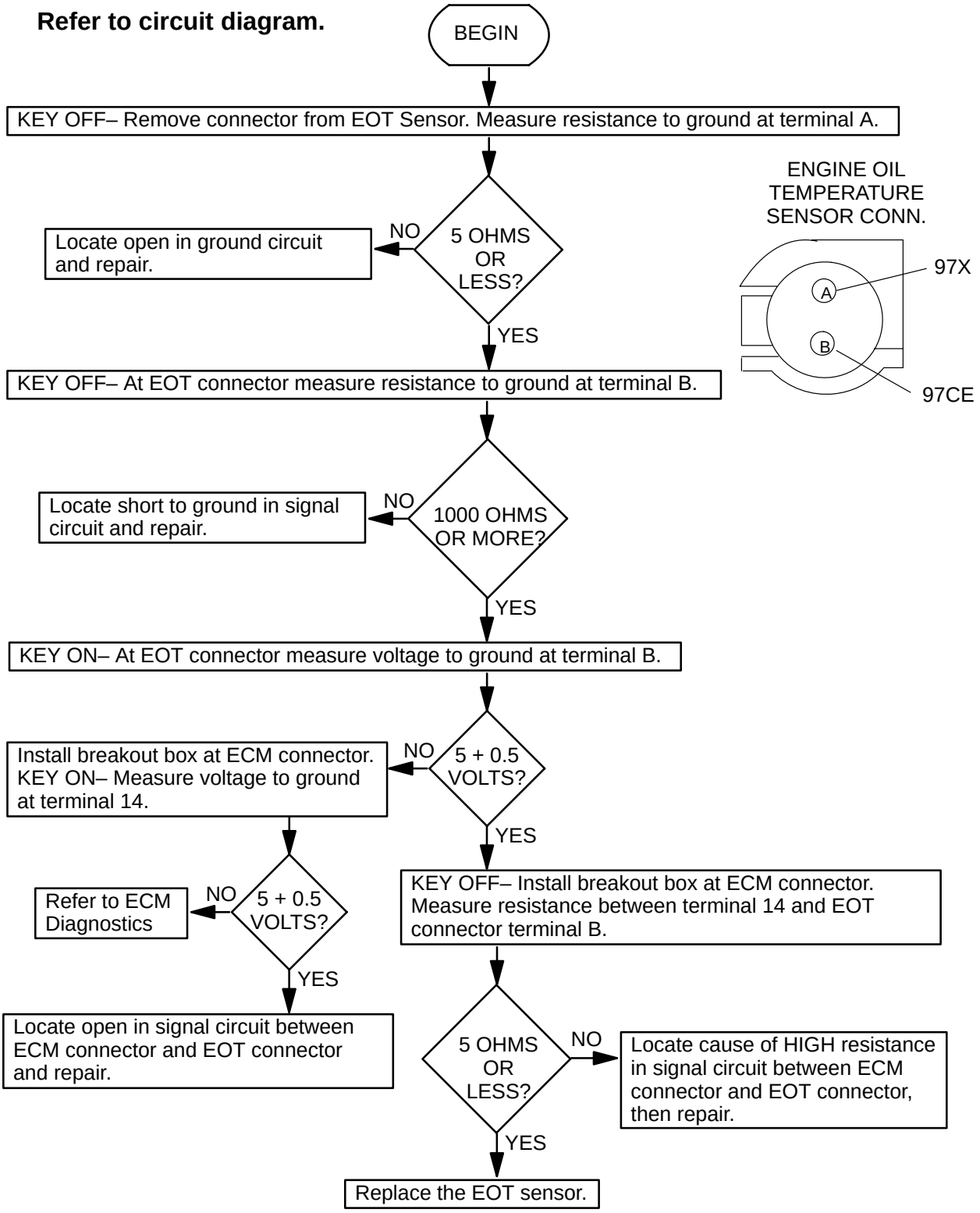
Code 312 out of range high,will be set if the signal voltage is more than 4.8 volts for more than 0.1 seconds. If this code is set, the ECM will default to ECT temperature or a default value of -4°F (-20°C) for starting or 212°F (100°C) for engine running operation. This code will cause the ECM to illuminate the Engine Warning light.

Code 312 may be set due to an open signal circuit between the ECM and the sensor or a short to a voltage source. A defective sensor may also cause code 312 to be set.

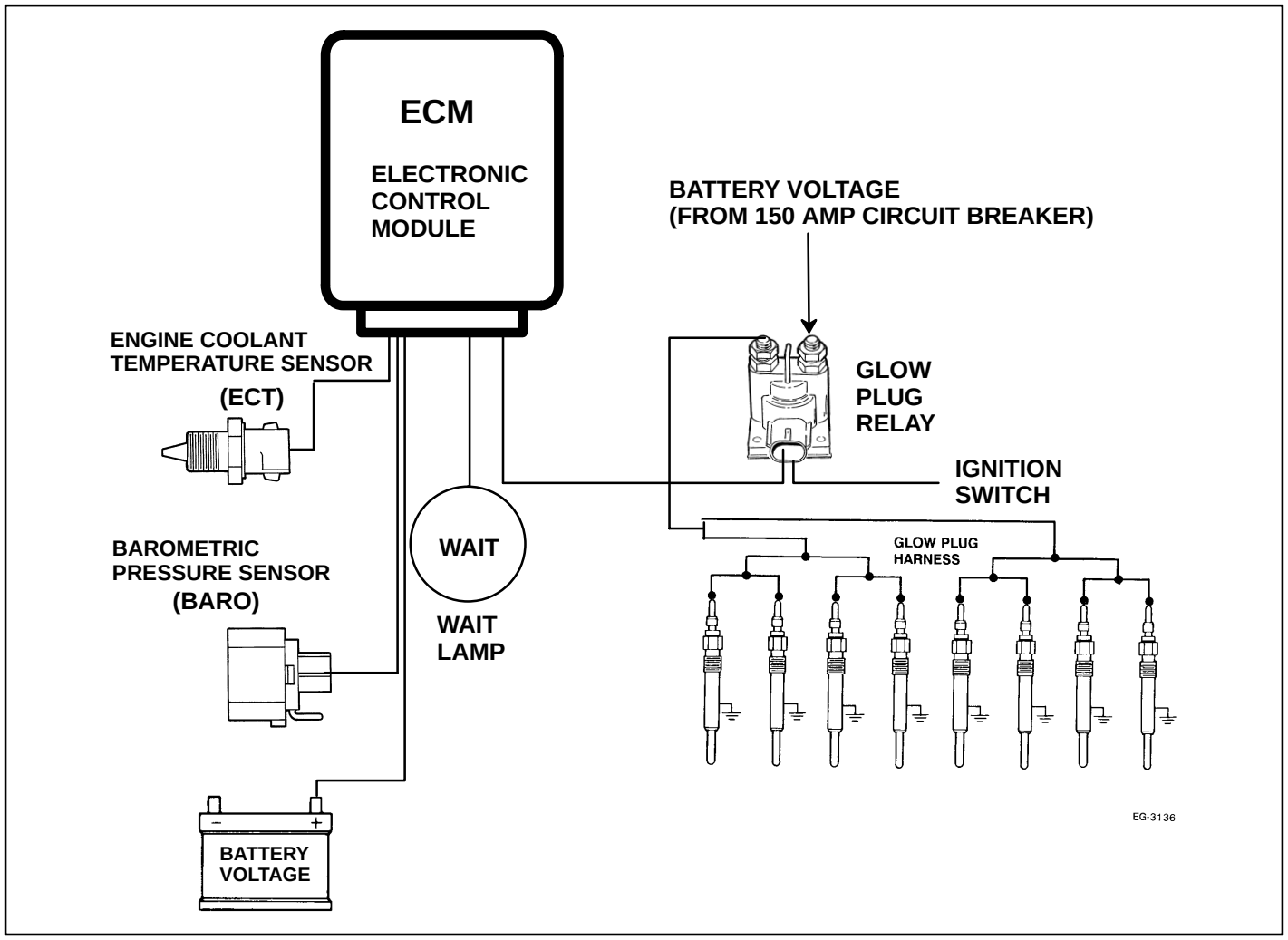
Engine Oil Temperature (EOT) Sensor (Cont.)

SENSOR DIAGNOSTICS

Refer to circuit diagram.


BEGIN
KEY OFF– Remove connector from EOT Sensor. Measure resistance to ground at terminal A.
5 OHMS OR LESS?
NO
Locate open in ground circuit and repair.
YES
KEY OFF– At EOT connector measure resistance to ground at terminal B.
1000 OHMS OR MORE?
NO
Locate short to ground in signal circuit and repair.
YES
KEY ON– At EOT connector measure voltage to ground at terminal B.
5 + 0.5 VOLTS?
NO
Install breakout box at ECM connector. KEY ON– Measure voltage to ground at terminal 14.
5 + 0.5 VOLTS?
NO
Refer to ECM Diagnostics
YES
Locate open in signal circuit between ECM connector and EOT connector and repair.
YES
KEY OFF– Install breakout box at ECM connector. Measure resistance between terminal 14 and EOT connector terminal B.
5 OHMS OR LESS?
NO
Locate cause of HIGH resistance in signal circuit between ECM connector and EOT connector, then repair.
YES
Replace the EOT sensor.
ENGINE OIL TEMPERATURE SENSOR CONN.
A
B
97X
97CE

Glow Plug Controller (GPC)



OUTPUT FUNCTIONS

Glow Plug Relay - Controls the current flow to the glow plugs. Glow plug relay "ON" time is controlled by the ECM and is a function of engine coolant temperature, barometric pressure and battery voltage. "ON" time normally varies between 10 to 120 seconds. The glow plugs are self limiting glow plugs and do not require to be cycled on and off. (The glow plug relay will only cycle on and off repeatedly when there is a system voltage condition greater than 13.0 volts.)

Glow Plug Wait Lamp - Lamp that indicates to the operator when the glow plugs have been on long enough to crank the engine. It is controlled by the ECM. Wait light on time is a function of engine coolant temperature, barometric pressure and battery voltage. "ON" time normally varies between 2 to 10 seconds.

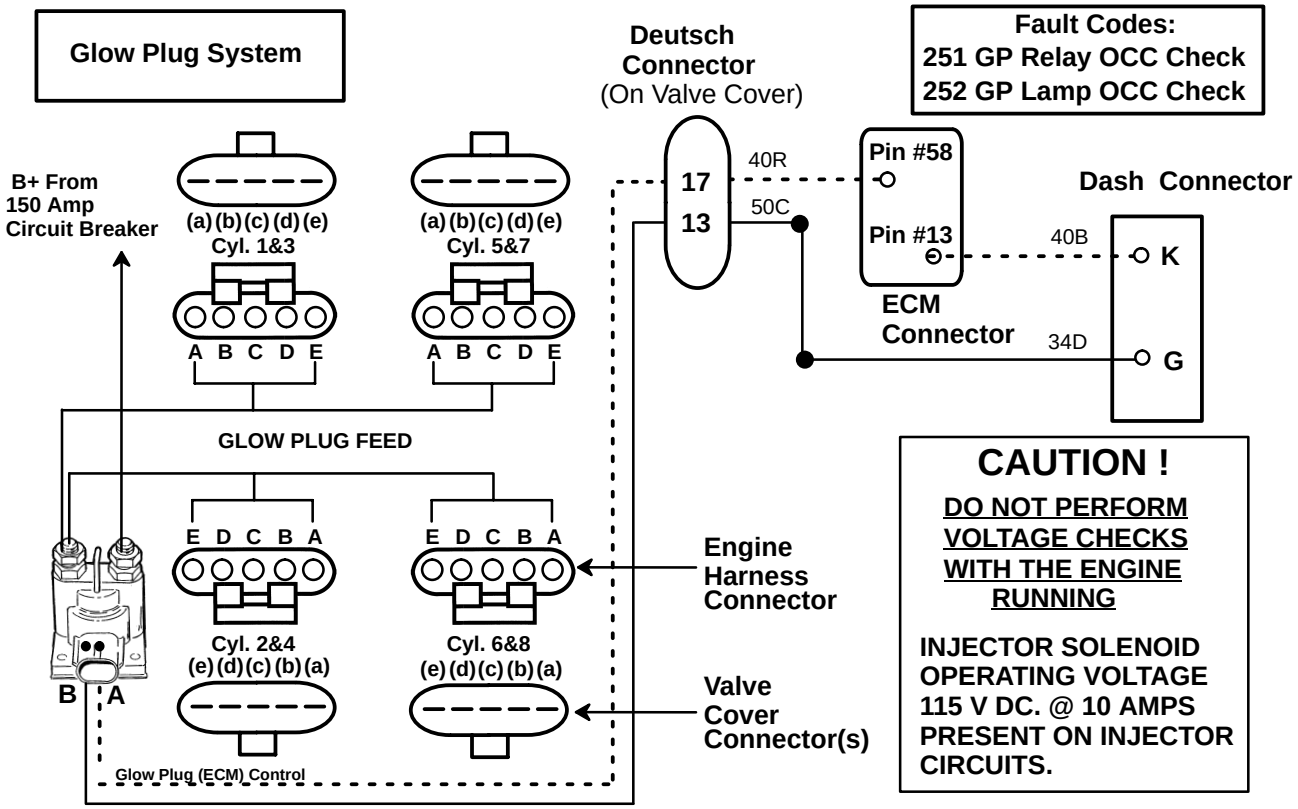
NOTE: *Wait light on time is independent from glow plug relay on time.*

FAULT DETECTION/MANAGEMENT

An open or shorted to ground glow plug relay or wait lamp circuit can be detected by an on demand output circuit check performed during the engine off tests.

Glow plug and glow plug harness problems can not be detected by the ECM.

Glow Plug Controller (GPC) (Cont.)



Glow Plug Relay Operation (Voltage Checks)

Test Points	Spec.	Comments
B+ terminal to ground	B+	Relay switch power, B+ should be present at all times (terminal with single 6 gauge wire). Check connection at starter or fusible links if no power (voltage) present.
Glow Plug Feed to Grd.	B+	Glow plug feed voltage should be present 10 to 120 sec. after key is cycled on, dependent upon battery voltage, barometric pressure (altitude) and engine coolant temperature.
B to Ground	B+	Relay coil power. Voltage should be present when ign. key is ON - Check fuse if no voltage.
Pin # 58 to Ground	0v / 12v	Glow plug control, switched to (grd) by ECM during operation. 0v = relay ON, 12v = relay off.

Glow Plug and Harness Operation

(Measure glow plug resistance to ground with the pigtail connector installed at the valve cover connector: then measure resistance from the glow plug feed stud to the harness connector).

Test Points			Comments
Glow Plug Number	Pigtail Connector to Ground (B-)	Relay to Harness Connector	
Spec	< .1 to 6 Ohm	< 6 Ohms	**Relay to Harness Connector** **NOTE: ALL ENGINE HARNESS CONNECTORS FOR GLOW PLUG/INJECTORS SHOULD BE DISCONNECTED BEFORE TAKING MEASUREMENTS** High resistance could indicate an open circuit in the engine harness between the glow plug connector and the relay.
#1			
#3			
#5			
#7			
#2			**Pigtail Connector to Ground B-** High resistance could indicate an open circuit in the UVC (under the valve cover) harness or in the glow plug. Glow plug resistance should measure .1 to 6 ohms dependent upon engine temperature.
#4			
#6			
#8			

Fault Code Descriptions

251 = OCC CHK performed by ECM during engine off test. Indicates high or low resistance in GP coil circuit.
252 = OCC CHK performed by ECM during engine off test. Indicates high or low resistance in GP lamp circuit.

Glow Plug Controller (GPC) (Cont.)

FUNCTION

The engine control system includes a Glow Plug Control System that controls the current flow to the glow plugs. Glow plug relay "ON" time is controlled by the ECM and is a function of Engine Coolant Temperature, Barometric Pressure, and Battery Voltage. Glow plug "ON" time varies between 10-120 seconds. Glow plugs are self limiting glow plugs and do not require to be cycled on and off. The glow plug relay will cycle on and off repeatedly, if battery voltage is greater than 13.0 volts.

OPERATION

Refer to circuit diagram for the following discussion.

Glow Plug System operation is dependent upon engine coolant temperature, barometric pressure and battery voltage. When the ignition switch is placed in the "ON" position,Terminal "B" (coil side) of the glow plug relay is supplied with battery voltage. Terminal "A" (coil side) of the relay is connected to Terminal 58 of the ECM. The ECM supplies battery ground to the glow plug relay coil via an internal driver transistor when coolant temperature, barometric pressure and battery voltage conditions require the glow plug system to warm the engine for starting.

Applying ground (B-) to terminal "A" causes the relay to switch and apply battery voltage (present at the large terminal containing a single wire leading to and connected to the B+ terminal of the starter solenoid) to the other large terminal which contains two wires. These wires now supply battery power to the glow plugs in the right and left cylinder heads.

The Glow Plug Wait Lamp is also turned on by the ECM when the glow plug relay is enabled.

NOTE: *Wait light on time is independent from glow plug relay on time.*

ECM DIAGNOSTICS

The ECM does not continuously monitor the glow plug control circuitry. An open or shorted to ground glow plug control relay on the control side (coil) circuit can be detected by an on demand output circuit check performed during the engine off test.

Fault codes can be retrieved using the electronic service tool or the STI Self Test Input Diagnostic Switch. If the ignition key is shutoff, the code will be stored as an active code.

FLASH CODE *251*
ATA CODE SID 38 FMI 11
GPC: OCC SELF TEST FAILED

Code 251 is set only during the Engine Off Standard Output Circuit check. This indicates that the ECM has performed an output circuit test, measured the voltage drop across the glow plug relay circuit and determined it is above or below specification. If the fault is present, the glow plug relay is not operating and the glow plugs are not enabled.

Possible Causes: Open feed circuit, open glow plug relay coil, an open or shorted GPC signal circuit.

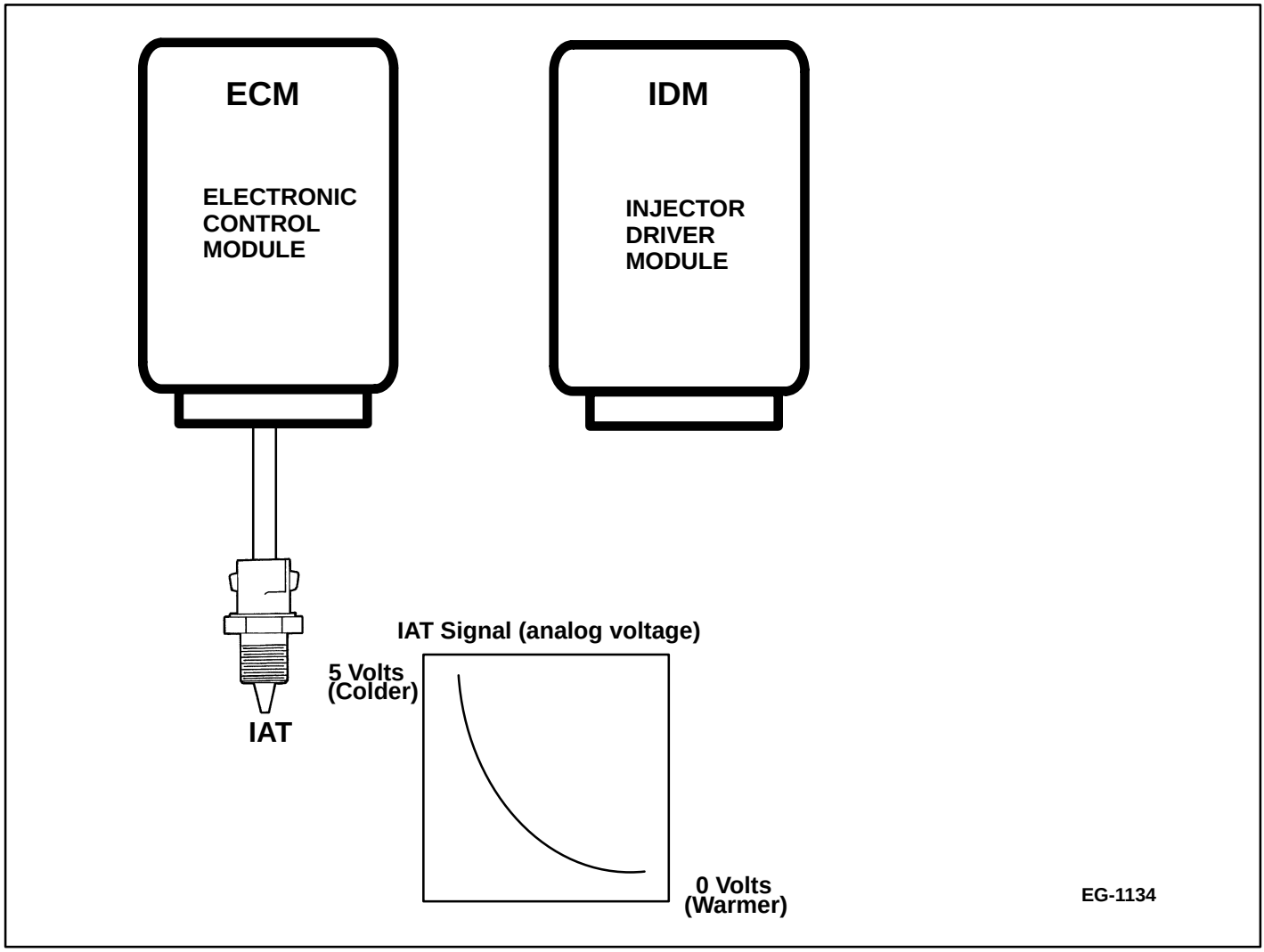
FLASH CODE *252*
ATA CODE SID 36 FMI 11
GLOW PLUG LAMP: OCC SELF TEST FAILED

Code 252 is set only during the Engine Off Standard Output Circuit check. This indicates that the ECM has performed an output circuit test, measured the voltage drop across the glow plug Wait Lamp circuit and determined it is above or below specification.

Possible Causes: Glow plug Wait Lamp burned out, open or shorted glow plug Wait Lamp circuit.

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Intake Air Temperature (IAT) Sensor



SIGNAL FUNCTIONS

The Intake Air Temperature (IAT) sensor is a thermistor type sensor that has a variable resistance that changes when exposed to different temperatures. When interfaced with the ECM it produces a 0-5 volt analog signal that will deduce temperature.

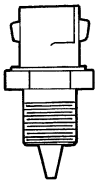
The IAT sensor's primary function is to measure intake air temperature.

FAULT DETECTION/MANAGEMENT

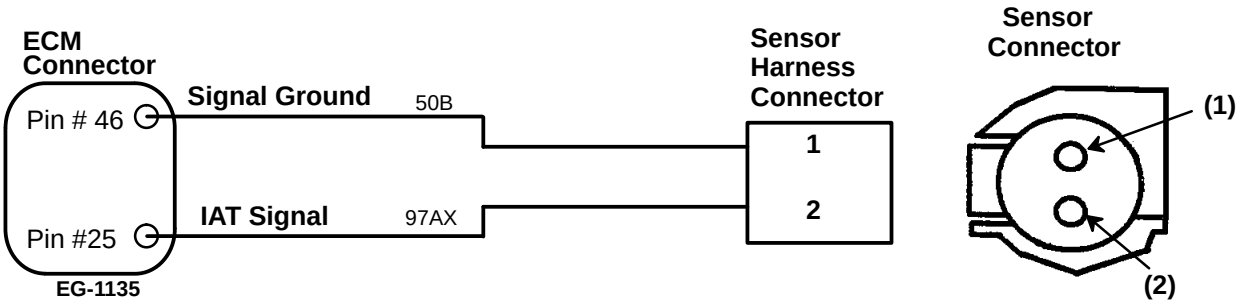
An IAT signal that is detected out of range high or low by the ECM will cause the engine to ignore the IAT signal.

Intake Air Temperature (IAT) Sensor (Cont.)

Intake Air Temperature Sensor (IAT)



Fault Codes:
154 Out of Range Low
155 Out of Range High



After removing connectors always check for damaged pins, corrosion, loose terminals etc.

Connector Checks to Ground -
(Check with Sensor Connector Disconnected and Ignition key off, all accessories off)

Test Points	Spec.	Comments
1 to Grd.	< 5 ohms	Resistance to grd, check with key off, if > 5 ohms the harness is open.
2 to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.

Connector Voltage Checks
(Check with sensor Connector Disconnected and Ignition Key On)

Test Points	Spec.	Comments
2 to Grd.	4.8 - 5.0v	Pull up voltage, if no or low voltage, circuit has open or high resistance or short to grd.
1 to Grd.	0 - .25v	If greater than .25 volts, signal wire is shorted to V Ref. or battery

Harness Resistance Checks
(Check with breakout box installed on engine harness only)

Test Points	Spec.	Comments
#46 to 1	< 5 ohms	Resistance from harness connector to 60 pin connector - Signal ground
#25 to 2	< 5 ohms	Resistance from harness connector to 60 pin connector - IAT Signal

Operational Voltage Checks
(Check with breakout box installed in line with the ECM)

Test Points (+) #25 to (-) #46				
Voltage	Temp. ° F	Temp. ° C	Resistance	Comments
1.72 v	122	50	10.9 K ohms	
3.09 v	68	20	37.34 K ohms	
3.897 v	32	0	68.75 K ohms	
4.33 v	0	-18	120.9 K ohms	
4.537 v	-40	-40	194.3 K ohms	

Circuit Fault Code Descriptions

Circuit Faults:
154 = Signal voltage was less than .127 volts for more than 0.2 seconds.
155 = Signal voltage was greater than 4.6 volts for more than 0.2 seconds.

Intake Air Temperature (IAT) Sensor (Cont.)

FUNCTION

The engine control system includes an Intake Air Temperature Sensor (IAT). The ECM measures the signal from the IAT sensor to determine the temperature of the air entering the engine. The ECM uses this data to adjust timing and fuel rate for starting in cold weather to limit smoke emissions.

OPERATION

The Intake Air Temperature Sensor is a thermistor type sensor which changes resistance when exposed to different air temperatures.

When the temperature of the intake air decreases, the resistance of thermistor increases which causes the signal voltage to increase. When the air temperature increases, the resistance of the thermistor decreases causing the signal voltage to decrease.

The IAT sensor is supplied a regulated 5 volt reference signal at terminal B from ECM terminal 25. A return circuit (ground) is supplied at terminal “1” from the ECM terminal 46. As the air temperature increases or decreases, the sensor changes resistance and provides the ECM with the air temperature signal voltage reading at terminal 25.

ECM DIAGNOSTICS

With the ignition key “ON”, the ECM continuously monitors the IAT signal to determine if it is within expected values. If the signal voltage is above or below the expected levels, the ECM will set a fault code.

If the IAT sensor is not sending a correct signal, the ECM will default to 77°F (25° C).

IAT faults can be retrieved using the Electronic Service Tool or by reading the flash codes from the warning light using the STI diagnostic switch. If the ignition key is shut off, the code will become an Inactive code. IAT codes will cause the Engine Warning light to be illuminated.

FLASH CODE *154*
ATA CODE PID 171 FMI 4
AMBIENT AIR TEMP SIGNAL OUT OF RANGE LOW

An out of range low code will be set if the ECM detects the signal voltage to be less than .127 volts for more than 0.2 seconds. If this fault is active, the ECM will default to a value of 77°F (25° C) for starting.

Code 154 may be set due to a short to ground in the signal circuit or a defective sensor.

FLASH CODE *155*
ATA CODE PID 171 FMI 3
AMBIENT AIR TEMP SIGNAL OUT OF RANGE HIGH

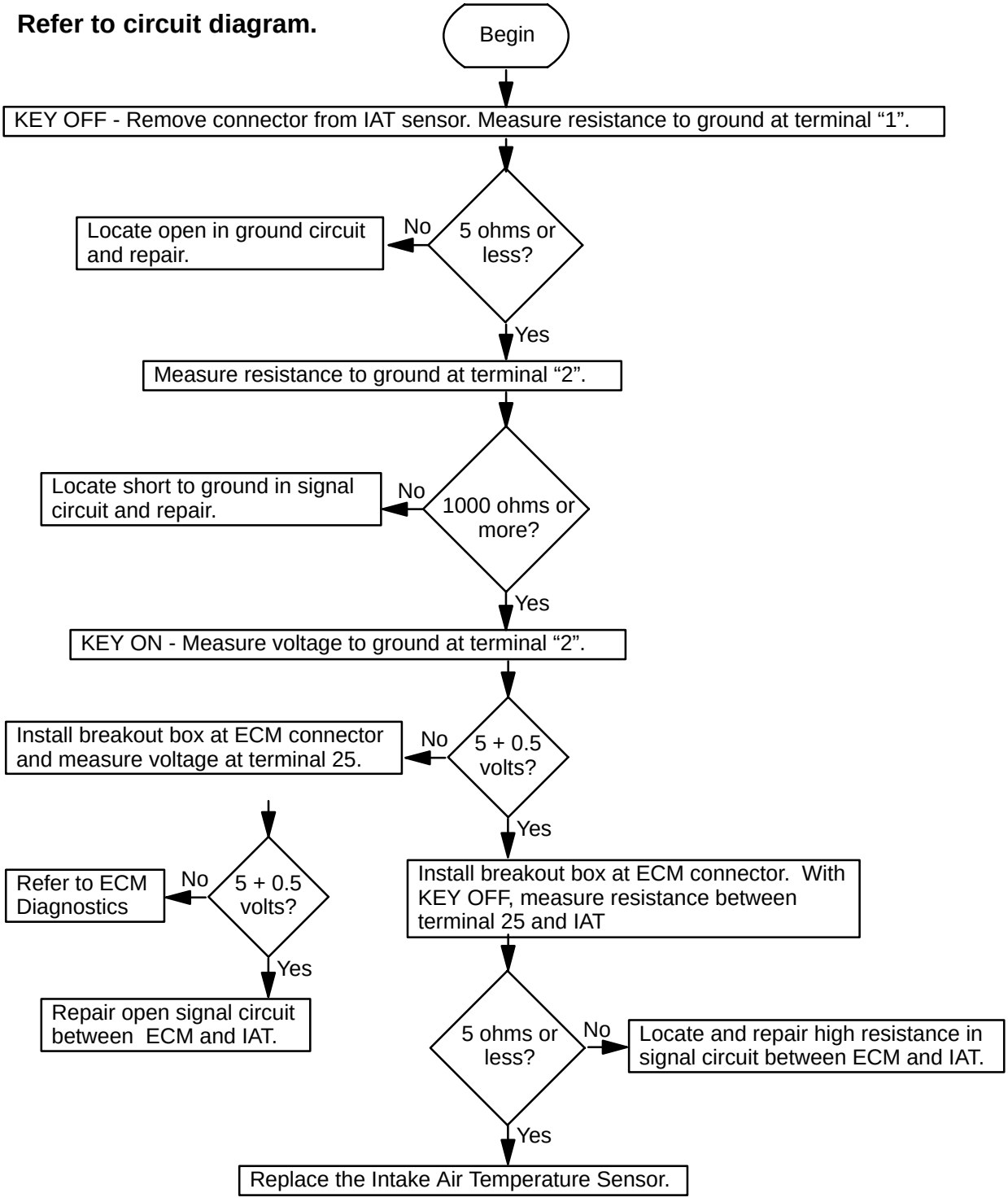
An out of range high code will be set if the ECM detects the signal voltage to be more than 4.6 volts for more than 0.2 seconds. If this fault is active, the ECM will default to a value of 77°F (25° C) for starting.

Code 155 may be set due to an open signal circuit between the ECM and the sensor or a short to a voltage source. A defective sensor may also cause code 155 to be set.

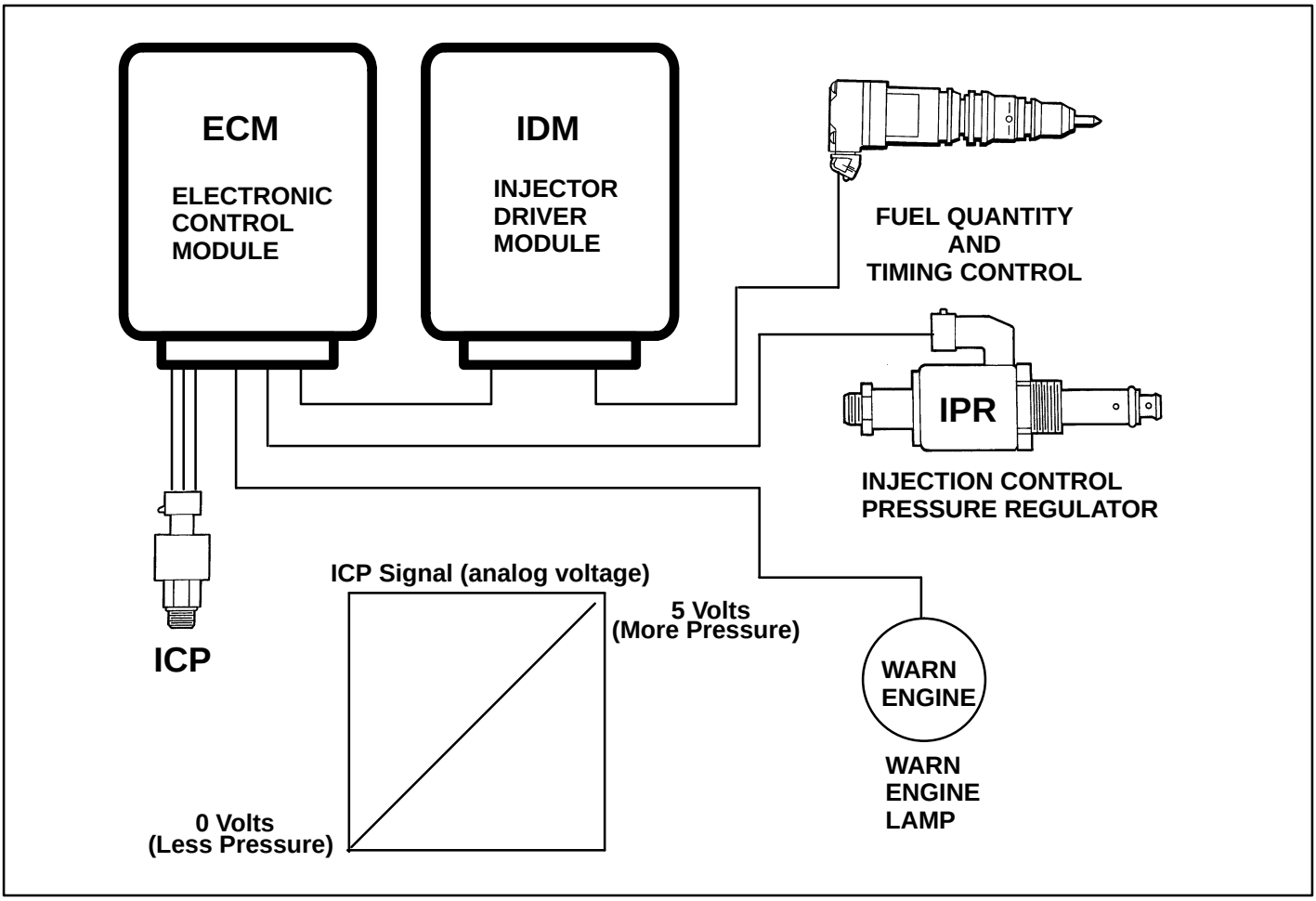
Intake Air Temperature (IAT) Sensor (Cont.)

SENSOR DIAGNOSTICS

Refer to circuit diagram.


Begin
KEY OFF - Remove connector from IAT sensor. Measure resistance to ground at terminal “1”.
5 ohms or less?
No
Locate open in ground circuit and repair.
Yes
Measure resistance to ground at terminal “2”.
1000 ohms or more?
No
Locate short to ground in signal circuit and repair.
Yes
KEY ON - Measure voltage to ground at terminal “2”.
5 + 0.5 volts?
No
Install breakout box at ECM connector and measure voltage at terminal 25.
Yes
Install breakout box at ECM connector. With KEY OFF, measure resistance between terminal 25 and IAT
5 ohms or less?
No
Locate and repair high resistance in signal circuit between ECM and IAT.
Yes
Replace the Intake Air Temperature Sensor.
5 + 0.5 volts?
No
Refer to ECM Diagnostics
Yes
Repair open signal circuit between ECM and IAT.

Injection Control Pressure (ICP) Sensor



SIGNAL FUNCTIONS

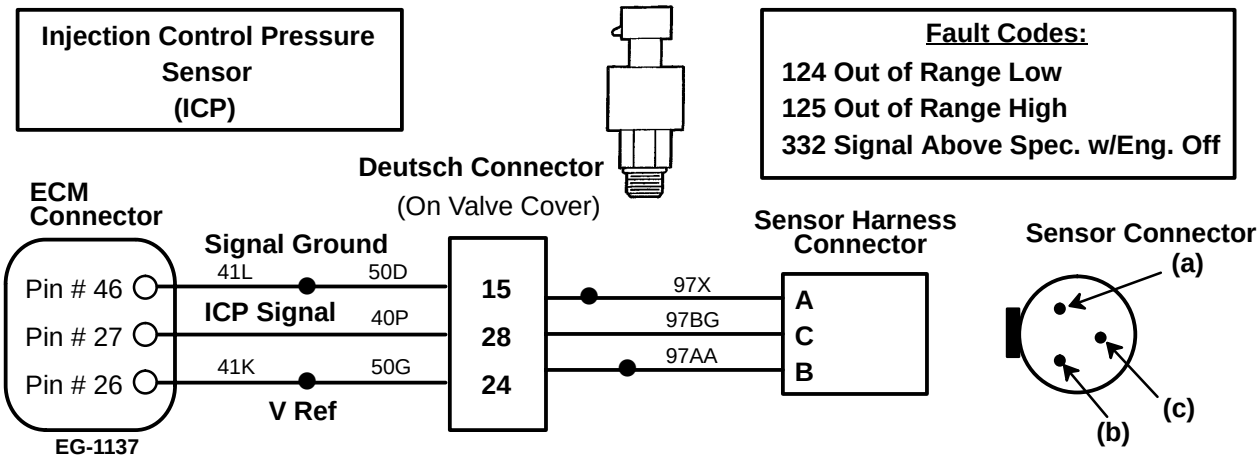
The Injection Control Pressure (ICP) sensor is a variable capacitance sensor that when supplied with a 5 volt reference signal from the ECM produces a linear analog voltage signal that indicates pressure.

The ICP sensor's primary function is to provide a feedback signal to indicate injection control pressure to enable the ECM to command the correct injector timing and pulse width and the correct injection control pressure for proper fuel delivery at all speed and load conditions.

FAULT DETECTION/MANAGEMENT

If the ECM detects a malfunctioning ICP sensor, the WARN lamp will illuminate. The ECM will go to open loop control of injection control pressure. (Operate from an estimated ICP pressure.)

Injection Control Pressure (ICP) Sensor (Cont.)



After removing connector always check for damaged pins, corrosion, loose terminals etc.

Connector Checks to Ground
(Check with Sensor Connector Disconnected and Ignition key off, all accessories off)

Test Points	Spec.	Comments
A to Grd.	< 5 ohms	Resistance to ground check with key off, if > than 5 ohms harness is open.
B to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.
C to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.

Connector Voltage Checks
(Check with sensor Connector Disconnected and Ignition Key On)

Test Points	Spec.	Comments
B to Grd.	5 volts ± .5	V Ref. check with key ON, if voltage not in spec., see V Ref circuit.
C to Grd.	0-.25 v	If greater than .25 volts, signal wire is shorted to V Ref. or battery

Harness Resistance Checks
(Check with breakout box installed on engine harness only)

Test Points	Spec.	Comments
#46 to A	< 5 ohms	Resistance from sensor connector to 60 pin connector - Signal ground
#26 to B	< 5 ohms	Resistance from sensor connector to 60 pin connector - V Ref
#27 to C	< 5 ohms	Resistance from sensor connector to 60 pin connector - ICP signal

Operational Voltage Checks
(Check with breakout box installed in line with the ECM)

Test Points (+) #27 to (-) #46

Voltage	PSI	MPA	Comments
.15 - .25 v	0	0	Atmospheric Pressure with Key ON and Engine OFF. (Altitude dependent)
1.0 v	580	4	Minimum required at engine cranking speed 130 RPM
.66 - .86 v	400 - 480	2.7 - 3.3	Normal warm idle voltage signal
3.66 v	2520	17.4	Snap accel or full load pressure signal

Circuit Faults: **Fault Code Descriptions**

124 = Signal voltage was less than .039 volts for more than 1.0 seconds.
125 = Signal voltage was greater than 4.90 volts for more than 1.0 seconds.
332 = Signal above 1.625 volts with engine off. (1160 psi, 8 MPa)

Injection Control Pressure (ICP) Sensor (Cont.)

FUNCTION

The engine control system includes an Injection Control Pressure Sensor. The ECM measures the signal from the ICP sensor to determine the Injection Control Pressure as the engine is running to modulate the Injection Control Pressure Regulator. This is a closed loop function which means the ECM continuously monitors and adjusts for ideal Injection Control Pressure determined by operating conditions such as load, speed, and temperature.

The ECM monitors the ICP signal to determine if the performance of the hydraulic system is satisfactory. During engine operation, if the ECM recognizes that the pressure reading is lower or higher than the value that was commanded, the ECM will set a fault code. This strategy is also used during the On Demand tests, commanded by the Electronic Service Tool and referred to as the Engine Running tests.

OPERATION

The Injection Control Pressure Sensor is a variable capacitance sensor that is supplied with a 5 volt reference voltage at terminal B by the ECM from terminal 26. The ICP sensor is also supplied with a return circuit (ground) at terminal A from ECM terminal 46. The ICP sensor sends a signal from terminal C of the sensor to ECM terminal 27.

The ICP signal voltage increases or decreases equally in proportion to an increase or decrease in injection control pressure.

ECM DIAGNOSTICS

The ECM continuously monitors the signal of the ICP sensor to determine if the signal is within an expected range. If the signal voltage is higher or lower than expected, the ECM will set a fault code. The ECM will then ignore the ICP sensor signal and will use a preset value determined by engine operating conditions. If the ignition key is shut off, the code will become an Inactive code.

ICP faults can be retrieved using the Electronic Service Tool or by reading the flash codes from the warning light using the STI diagnostic switch.

If the ignition key is shut off, the code will become an Inactive code. ICP codes will cause the Engine Warning light to be illuminated.

FLASH CODE *124*

ATA CODE PID 164 FMI 4

ICP SIGNAL OUT OF RANGE LOW

An out of range low code 124 will be set by the ECM if the signal voltage is less than .039 volts for more than 1.0 seconds.

Code 124 may be set due to an open or short to ground on the signal circuit, a defective sensor or an open VREF circuit.

FLASH CODE *125*

ATA CODE PID 164 FMI 3

ICP SIGNAL OUT OF RANGE HIGH

An out of range high code 125 will be set by the ECM if the signal voltage is greater than 4.9 volts for more than 1.0 seconds.

Code 125 may be set by an open return circuit, short to a voltage source on the ICP signal circuit or a defective sensor.

FLASH CODE *332*

ATA CODE PID 164 FMI 13

INJECTION CONTROL PRESsure ABOVE SPECification WITH ENGINE OFF

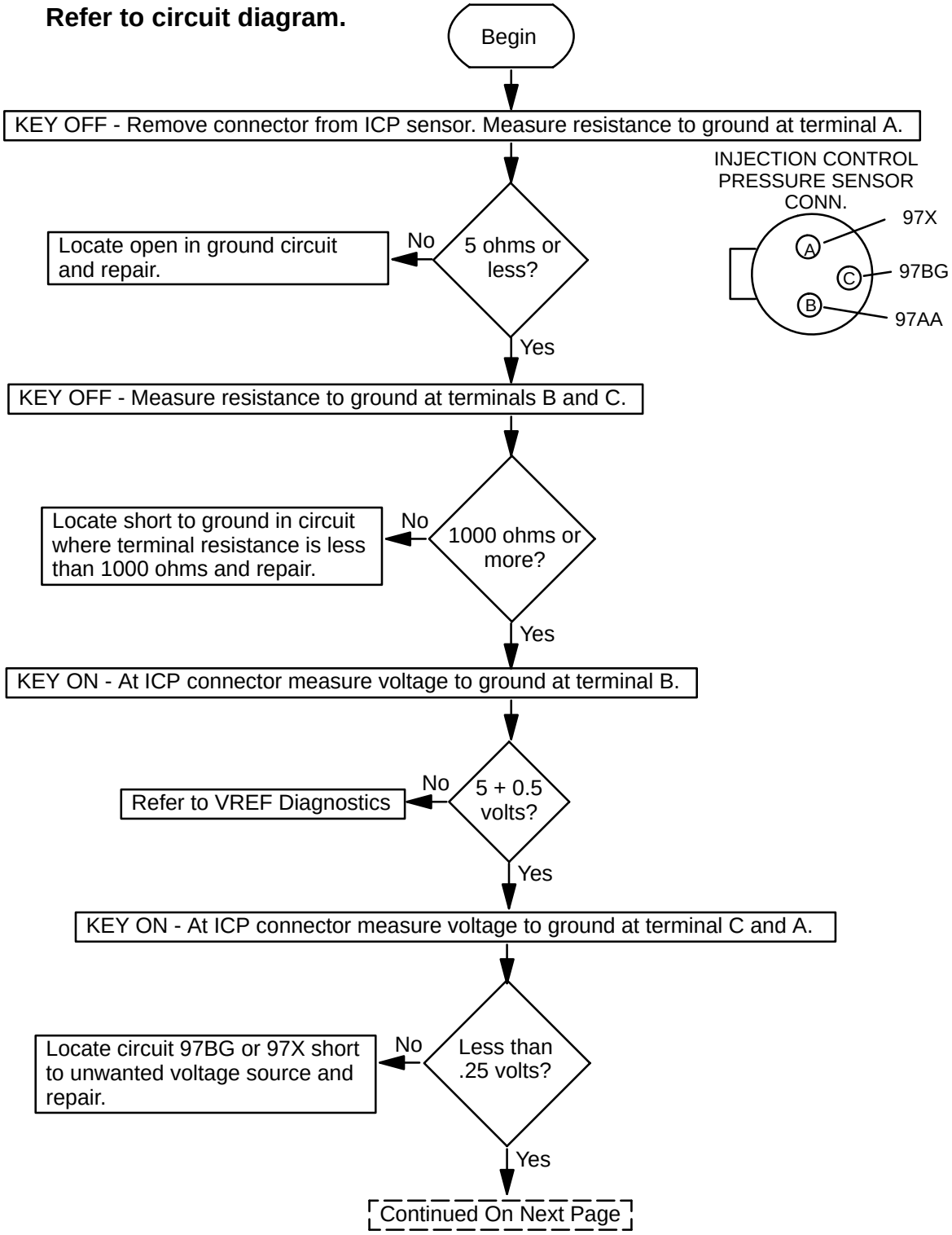
Code 332 will be set by the ECM, if the signal from the ICP sensor is higher than expected with the engine not running. If the ECM detects this fault, the ECM will ignore the ICP signal and will operate the IPR with fixed values determined from engine operating conditions.

Code 332 may be caused by a defective sensor or a biased circuit.

Injection Control Pressure (ICP) Sensor

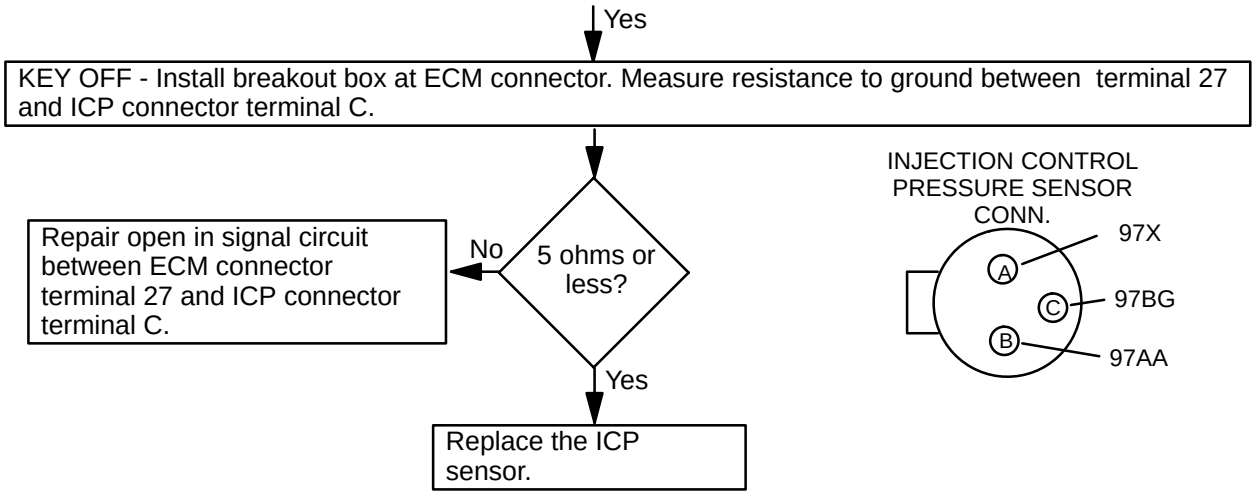
SENSOR DIAGNOSTICS

Refer to circuit diagram.

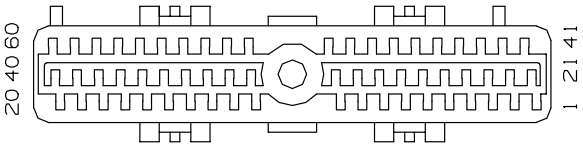

Begin
KEY OFF - Remove connector from ICP sensor. Measure resistance to ground at terminal A.
INJECTION CONTROL PRESSURE SENSOR CONN.
97X
A
C
97BG
B
97AA
5 ohms or less?
No
Locate open in ground circuit and repair.
Yes
KEY OFF - Measure resistance to ground at terminals B and C.
1000 ohms or more?
No
Locate short to ground in circuit where terminal resistance is less than 1000 ohms and repair.
Yes
KEY ON - At ICP connector measure voltage to ground at terminal B.
5 + 0.5 volts?
No
Refer to VREF Diagnostics
Yes
KEY ON - At ICP connector measure voltage to ground at terminal C and A.
Less than .25 volts?
No
Locate circuit 97BG or 97X short to unwanted voltage source and repair.
Yes
Continued On Next Page

Injection Control Pressure (ICP) Sensor

SENSOR DIAGNOSTICS

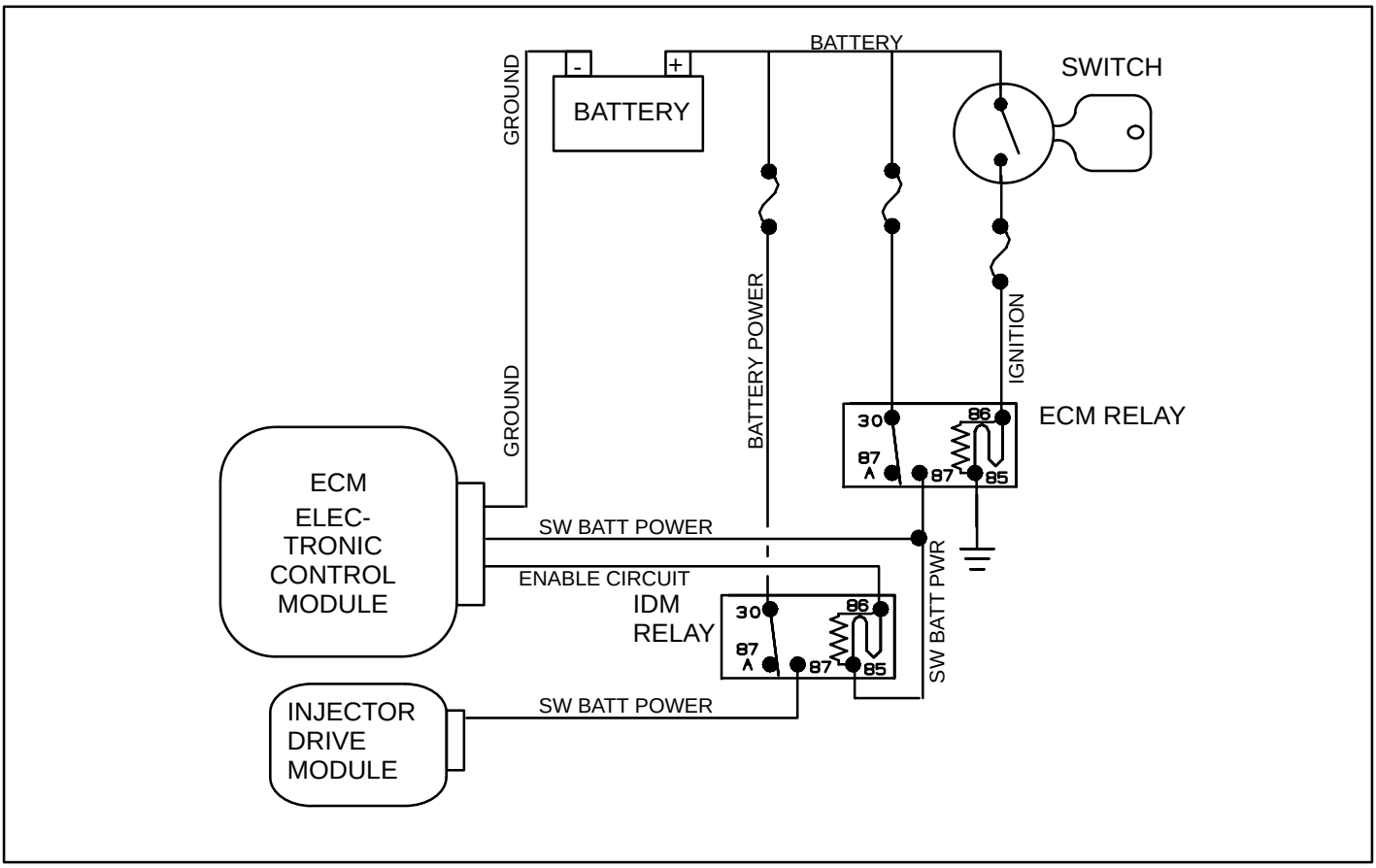

Yes
KEY OFF - Install breakout box at ECM connector. Measure resistance to ground between terminal 27 and ICP connector terminal C.
5 ohms or less?
No
Repair open in signal circuit between ECM connector terminal 27 and ICP connector terminal C.
Yes
Replace the ICP sensor.
INJECTION CONTROL PRESSURE SENSOR CONN.
97X
A
C
97BG
B
97AA

ELECTRONIC CONTROL MODULE (ECM)



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Injector Driver Module Power Circuits (IDM PWR)



CIRCUIT FUNCTIONS

The IDM receives switched 12 volt operating power with the key ON from the IDM power relay.

IDM SWITCHED POWER

Turning the key ON energizes the ECM power relay causing 12 volt battery power to be applied to the IDM relay coil. The IDM relay is enabled when the coil is grounded through ECM terminal 33. With the relay energized (enabled), battery power is applied to the IDM at terminal 14.

FAULT DETECTION MANAGEMENT

The IDM power circuits are not continuously monitored. If the circuit is not operating the engine will not run. The ECM uses the Output Circuit Check (OCC) initiated during a Standard Test to test the IDM relay control coil circuits for opens or shorts (high and low).

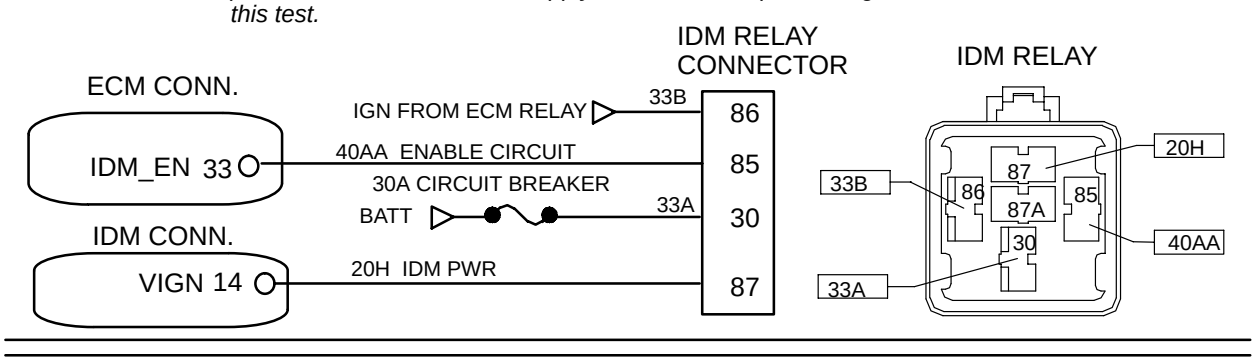
On each power up the IDM performs a self check. If internal faults are detected, a fault code will be set during an Engine Standard Test.

Injector Driver Module Power Circuits (IDM PWR) - Cont.

Injector Drive Module Power (IDM PWR)

Fault Codes:
243 IDM PWR Relay OCC Fault
522 IDM Internal Fault
523 IDM PWR Voltage Low

NOTE: *Verify the ECM is ON (warning light turns on during self-test when key is turned on) . If the ECM is not receiving power refer to ECM Power Supply Circuits before performing this test.*



Connector Checks To Ground

IDM Relay removed from connector, IDM disconnected and breakout box installed at ECM connection.

Test Points	Spec.	Comments
KEY OFF		**At Connector for IDM PWR Relay**
#30 to Grd.	12 ± 1.5 volts	< less than 10.5 v check connections, if 0 volts check for open/short to ground or blown fuse
#86 to Grd.	0 volts	0 volts expected with ign. key “OFF”.
#87 to Grd.	> 1000 ohms	< less than 1000 ohms, check for short to ground
#85 to Grd.	> 1000 ohms	< less than 1000 ohms, check for short to ground
KEY ON		**At Connector for IDM PWR Relay**
#86 to Grd.	12 ± 1.5 volts	< less than 10.5 v check connections, if 0 volts check for open/short to ground or blown fuse
KEY ON		**At ECM Connector**
#33 to 37	12 ± 1.5 volts	< less than 10.5 v check connections. ECM is defective or other condition is causing the ECM not to enable (ground) terminal 33.
KEY ON		**At connector for IDM PWR Relay**
#30 to #85	12 ± 1.5 volts	< less than 10.5 v check connections, if 0 volts repair open enable circuit between ECM and IDM Relay connectors
KEY OFF		**Test circuit between IDM Connector and IDM Relay Connector.**
Relay #87 to IDM #14	< 5 ohms	Greater than 5 ohms, repair open in ignition circuit. Less than 5 ohms, replace the IDM relay or connector.

Fault Code Descriptions

243 = IDM relay circuit has high or low resistance detected by ECM during an Engine Off Test. {Output Circuit Test}
522 = IDM has detected an internal fault, if no other fault codes present replace IDM.
523 = IDM power has been detected low by IDM.

Injector Driver Module Power Circuits (IDM PWR) - Cont.

EXTENDED SYSTEM DESCRIPTION

The Injector Driver Module (IDM) Power Relay acts as an ON/OFF switch that the ECM uses to turn the IDM on and off.

The ECM uses sensors to monitor Injection Control Pressure parameters. When starting the engine, if the ECM determines that any of these parameters are out of safe operating range, the ECM does not enable the IDM Power Relay, which prevents the engine from starting.

If the engine is started, and parameters are detected out of the safe operating range, the engine will derate, then disable the IDM Power Relay, which turns the IDM off, causing the engine to shut down.

Refer to the circuit diagram for the following discussion.

The IDM PWR relay controls battery power to the Injector Driver Module (IDM) through IDM connector terminal 14. Battery power is available at all times to relay connector at terminal 30. The feed circuit is protected by a 30A circuit breaker.

When the key switch is turned ON, power from ECM PWR relay is applied to the IDM PWR relay control coil at terminal 85. The IDM relay control coil ground circuit (40AA) is connected to ECM connector terminal 33. The ECM switches ECM terminal 33 between 0 and 12 volts to enable or disable the IDM relay. When terminal 33 is at 0 volts, the IDM relay energizes.

When the IDM PWR relay is energized, battery power passes through the normally open relay contacts (30 to 87) and on circuit 20H to IDM connector terminal 14 (IDM VIGN). The IDM power ground is from IDM terminal 26, through circuits 20R/113 to the negative battery terminal.

If the IDM is not powered, the engine will not run.

ECM DIAGNOSTICS

The ECM uses the Output Circuit Check (OCC) to test the IDM relay control coil circuit for short circuits (high or low) and opens in the circuit. Use the Prolink EST to perform the OCC test. When the test is complete, the Prolink will indicate if there were faults detected and what the Flash Code number is.

Flash Code *243*

SID 37 FMI 11

ECM: *IDM _Enable OCC Fault*

If the IDM detects a fault in the IDM circuit during the OCC test, Flash Code 243 will be set. This indicates that circuit 40AA is shorted (high or low) open or no power is present in circuit 33B to energize the IDM relay.

When Flash Code 243 occurs, it can also cause Flash Codes 253, 523, 541 or 543 to be set. Flash codes 253, 523, 541, and 543 can be caused by several conditions. This section only discusses the IDM POWER RELAY circuits that could cause the codes to set.

Injector Driver Module Power Circuits (IDM PWR) - Cont.

ECM DIAGNOSTICS (CONTINUED)

FLASH CODE 522
SID 233 FMI 12
IDM: *IDM INTERNAL FAILURE*

FLASH CODE 523
SID 233 FMI 4
IDM: *IDM POWER VOLTAGE LOW*

Code 523 can be caused by:

1. Faulty IDM PWR Relay control circuit (will cause code 243 to set when performing an OCC test).
2. Excessive voltage drop in circuit 20H.
3. Low voltage in 33A to the IDM PWR Relay from the 30A circuit breaker.
4. A defective IDM PWR Relay.

TROUBLESHOOTING

The test included in this section systematically checks the entire IDM Power Relay System.

If Flash Codes 243, 253, 523, 541 or 543 are active, perform the following test. Refer to the circuit diagram located in this section while using test procedure.

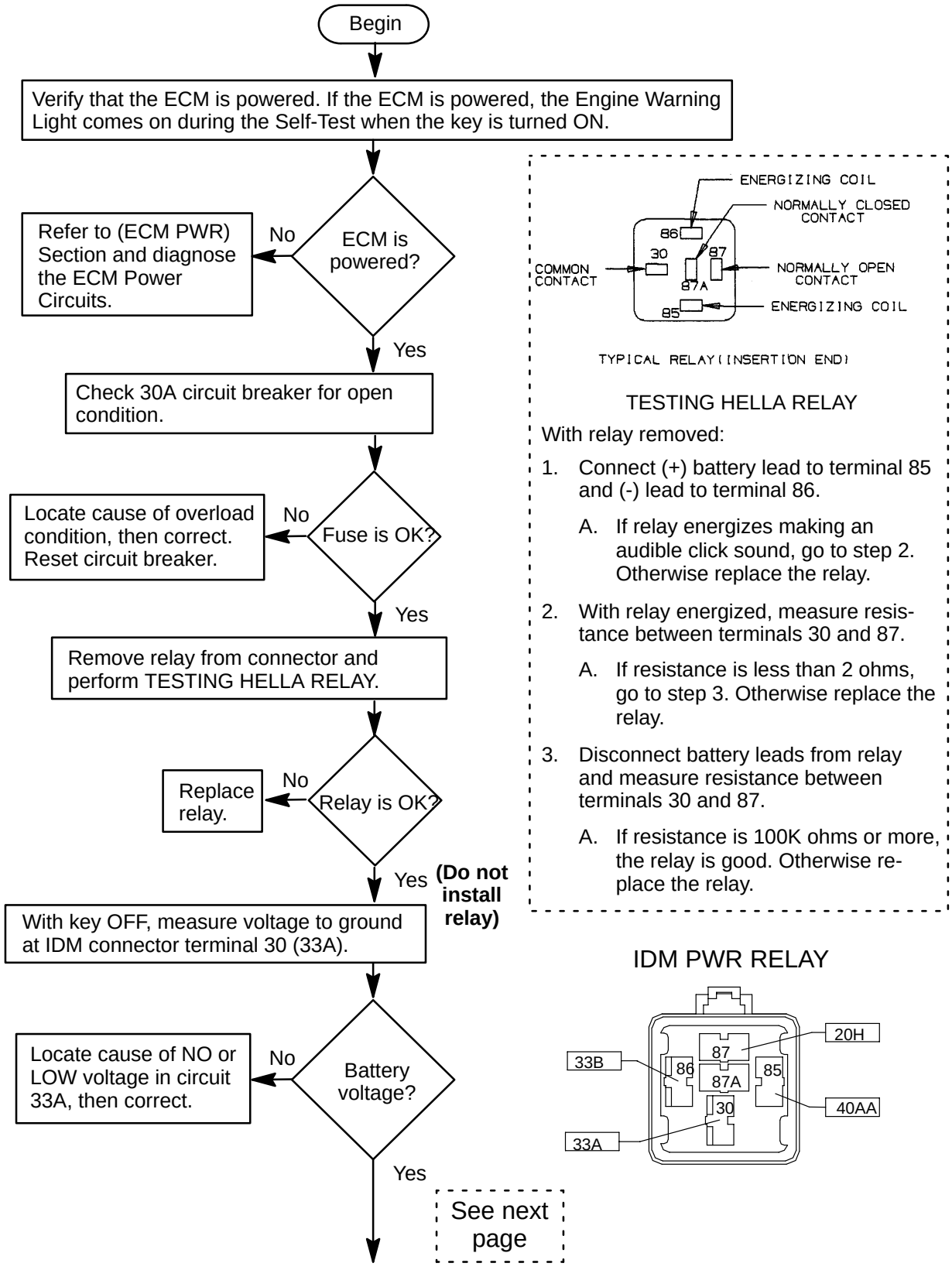
BEFORE TROUBLESHOOTING

Before Performing the test(s) included in this section:

1. Make sure batteries are fully charged! Check battery cables and grounds for clean, tight connections free of damage and corrosion. Voltage tests will give inaccurate readings if batteries are not fully charged.
2. Inspect connectors for pushed back, loose or damaged (spread or bent) terminals, or wires with cut strands, etc. the wires and connections must be free of damage or corrosion. When some connectors corrode, a light white residue is present that must be removed.
3. Inspect suspect circuit grounds for clean, tight connections, free of damage.

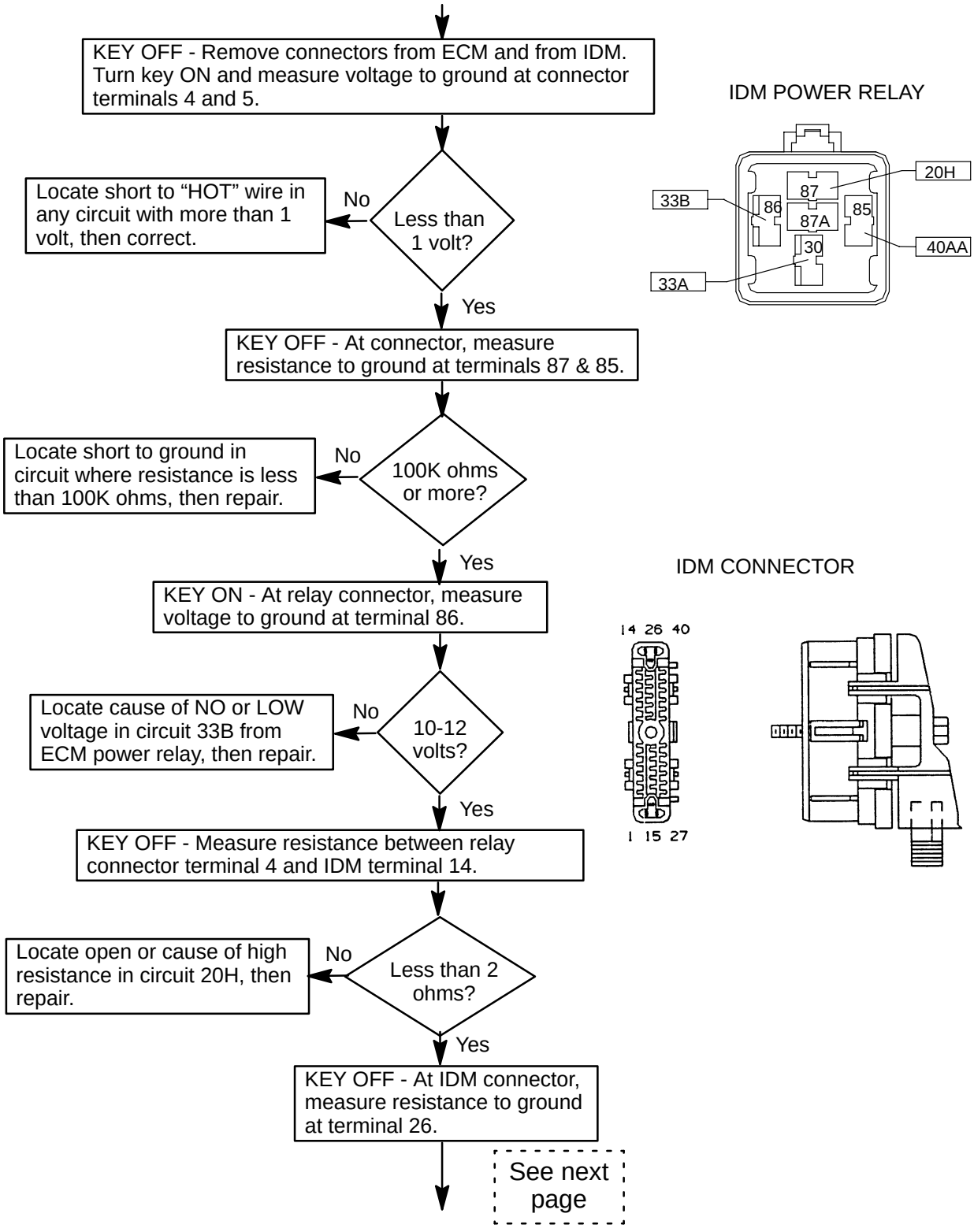
Injector Driver Module Power Circuits (IDM PWR) - Cont.

SENSOR DIAGNOSTICS


Begin
Verify that the ECM is powered. If the ECM is powered, the Engine Warning Light comes on during the Self-Test when the key is turned ON.
ECM is powered?
No
Refer to (ECM PWR) Section and diagnose the ECM Power Circuits.
Yes
Check 30A circuit breaker for open condition.
Fuse is OK?
No
Locate cause of overload condition, then correct. Reset circuit breaker.
Yes
Remove relay from connector and perform TESTING HELLA RELAY.
Relay is OK?
No
Replace relay.
Yes
(Do not install relay)
With key OFF, measure voltage to ground at IDM connector terminal 30 (33A).
Battery voltage?
No
Locate cause of NO or LOW voltage in circuit 33A, then correct.
Yes
See next page
ENERGIZING COIL
NORMALLY CLOSED CONTACT
COMMON CONTACT
NORMALLY OPEN CONTACT
ENERGIZING COIL
86
30
87
87A
85
TYPICAL RELAY (INSERTION END)
TESTING HELLA RELAY
With relay removed:
1. Connect (+) battery lead to terminal 85 and (-) lead to terminal 86.
A. If relay energizes making an audible click sound, go to step 2. Otherwise replace the relay.
2. With relay energized, measure resistance between terminals 30 and 87.
A. If resistance is less than 2 ohms, go to step 3. Otherwise replace the relay.
3. Disconnect battery leads from relay and measure resistance between terminals 30 and 87.
A. If resistance is 100K ohms or more, the relay is good. Otherwise replace the relay.
IDM PWR RELAY
20H
33B
87
86
87A
85
30
40AA
33A

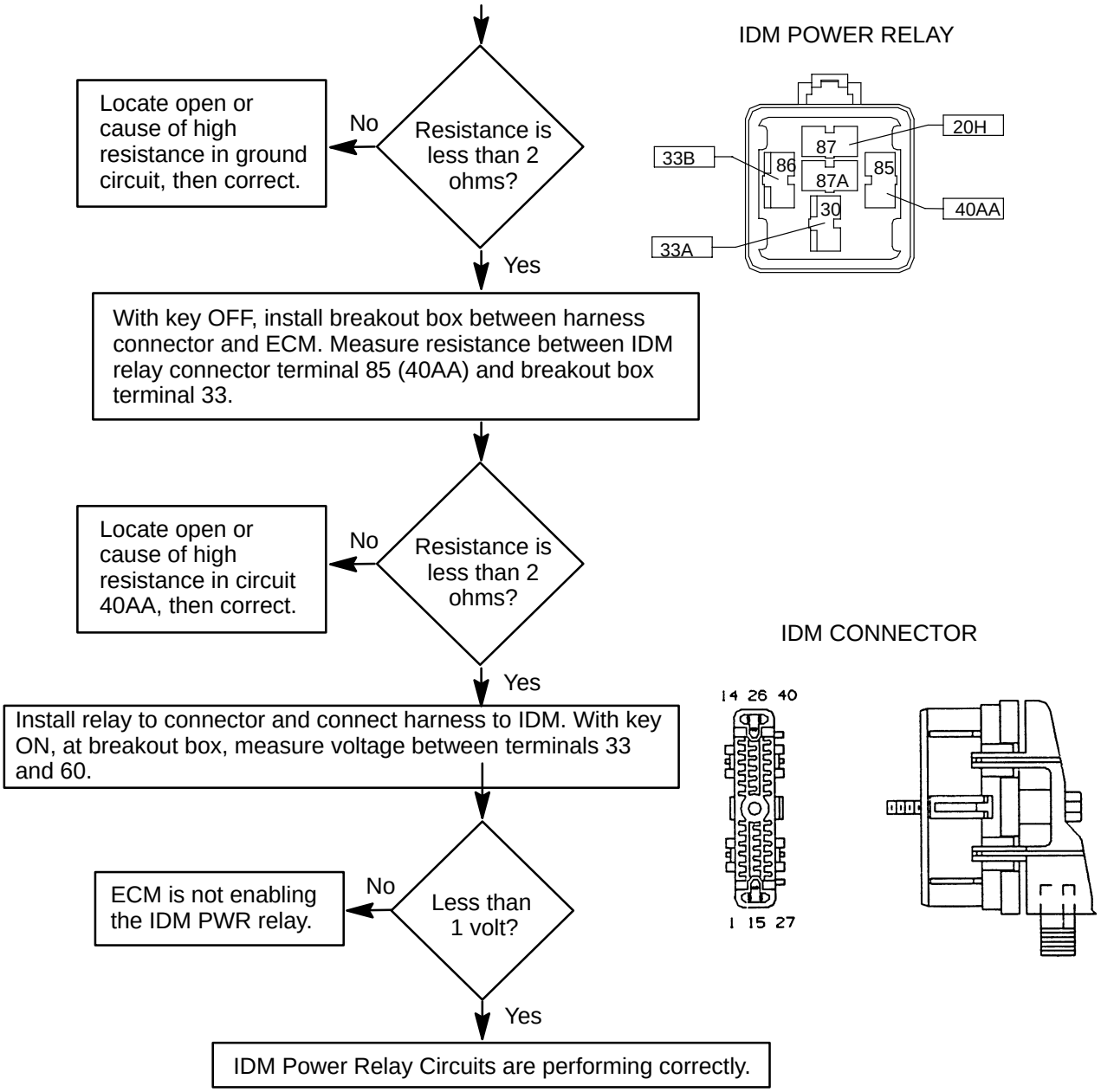
Injector Driver Module Power Circuits (IDM PWR) - Cont.

TESTING IDM PWR RELAY AND RELATED CIRCUITS


KEY OFF - Remove connectors from ECM and from IDM. Turn key ON and measure voltage to ground at connector terminals 4 and 5.
Less than 1 volt?
No
Locate short to “HOT” wire in any circuit with more than 1 volt, then correct.
Yes
KEY OFF - At connector, measure resistance to ground at terminals 87 & 85.
100K ohms or more?
No
Locate short to ground in circuit where resistance is less than 100K ohms, then repair.
Yes
KEY ON - At relay connector, measure voltage to ground at terminal 86.
10-12 volts?
No
Locate cause of NO or LOW voltage in circuit 33B from ECM power relay, then repair.
Yes
KEY OFF - Measure resistance between relay connector terminal 4 and IDM terminal 14.
Less than 2 ohms?
No
Locate open or cause of high resistance in circuit 20H, then repair.
Yes
KEY OFF - At IDM connector, measure resistance to ground at terminal 26.
See next page
IDM POWER RELAY
87
20H
33B
86
87A
85
30
40AA
33A
IDM CONNECTOR
14 26 40
1 15 27

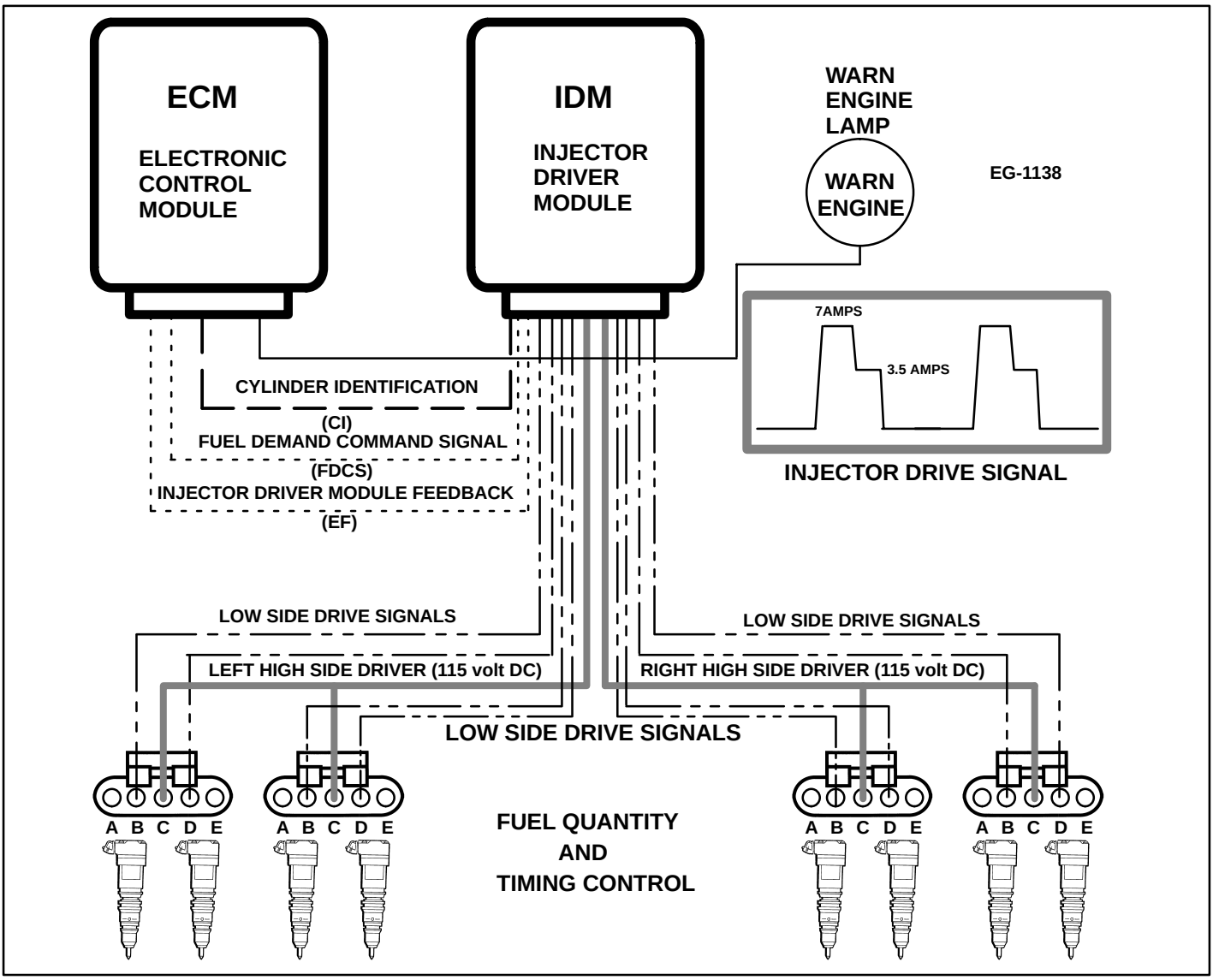
Injector Driver Module Power Circuits (IDM PWR) - Cont.

TESTING IDM PWR RELAY AND RELATED CIRCUITS


Resistance is less than 2 ohms?
No
Locate open or cause of high resistance in ground circuit, then correct.
Yes
With key OFF, install breakout box between harness connector and ECM. Measure resistance between IDM relay connector terminal 85 (40AA) and breakout box terminal 33.
Resistance is less than 2 ohms?
No
Locate open or cause of high resistance in circuit 40AA, then correct.
Yes
Install relay to connector and connect harness to IDM. With key ON, at breakout box, measure voltage between terminals 33 and 60.
Less than 1 volt?
No
ECM is not enabling the IDM PWR relay.
Yes
IDM Power Relay Circuits are performing correctly.
IDM POWER RELAY
87
20H
33B
86
87A
85
30
40AA
33A
IDM CONNECTOR
14 26 40
1 15 27

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Injector Drive Circuit Operation



SIGNAL FUNCTIONS

High Side Drive Outputs (Right and Left Bank) - The high side drive output function is to supply to the injectors a power supply of 115 volt DC at a maximum of 10 amps. This power supply is available to the injectors on a continuous basis.

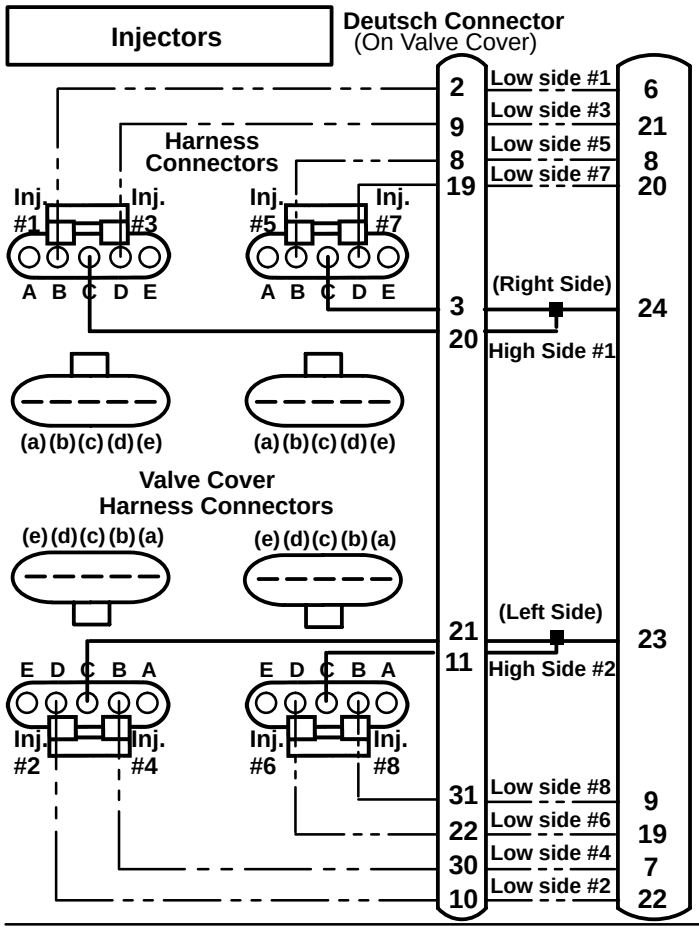
Low Side Drive Outputs - The low side drive outputs control the injector on time (fuel quantity), timing (in relation to TDC) and sequencing (firing order). The IDM controls (fires) each individual injector by completing the ground circuit to each injector solenoid. A valid Cylinder Identification (CI) and Fuel Demand Command Signal (FDCS) must be sent from the ECM to the IDM before an injector will be allowed to fire.

FAULT DETECTION/MANAGEMENT

The Injector Driver Module (IDM) is capable of detecting, while the engine is running individual injector open and shorts to either ground or battery. It is also capable of detecting right or left bank high side opens or shorts to ground. A special On-Demand Buzz test will also allow the operator to enable all injector solenoids while the engine is off to verify circuit operation. **IDM detected diagnostic fault codes will not be transmitted if the EF line is not functioning, however, the engine will function normally.**

If a short to ground condition is detected on an individual injector, (low side), the IDM will discontinue the power to the bank with the shorted injector, enable the WARN engine lamp and operate the engine on four cylinders.

Injector (INJ) Drive Circuit Operation (Cont.)



Fault Codes:

NOTE: (Last code digit refers to INJ or Bank #)

421-428 High to low side open inj. #1-#8
431-438 High to low side short inj. #1-#8
441-448 Low side short to B+ inj. #1-#8
451-458 Low side short to grd. inj. #1-#8
511 Multiple faults on bank #1 (right)
512 Multiple faults on bank #2 (left)
513 High side open right group
514 High side open, left group
515 High side #1 (right) short to grd.
521 High side #2 (left) short to grd.
524 High sides shorted together
544 Injector Fault in Bank 2
545 Injector Fault in Bank 1

INJECTION DRIVER MODULE CONNECTOR

EG-1139

CAUTION !

DO NOT PERFORM VOLTAGE CHECKS WITH THE ENGINE RUNNING

INJECTOR SOLENOID OPERATING VOLTAGE 115 V DC. @ 10 AMPS PRESENT ON INJECTOR CIRCUITS.

After removing connectors always check for damaged pins, corrosion, loose terminals etc.

NOTE: Test all injector harness and valve cover connectors at Test Points indicated.

Engine Harness Connector Check to Ground

Test Points	Spec.	Comments
B	> 1000 ohms	Injector low side - codes 451-458 may be set if shorted to grd.
C	> 1000 ohms	Injector power feed high side - codes 515 or 521 may be set if shorted to grd.
D	> 1000 ohms	Injector low side - codes 451-458 may be set if shorted to grd.

Valve Cover Gasket Connector to Ground
(Check with pigtail connector installed on gasket connector)

Test Points	Spec.	Comments
B	> 1000 ohms	Injector low side - codes 451-458 may be set if shorted to grd.
C	> 1000 ohms	Injector power feed high side - codes 515 or 521 may be set if shorted to grd.
D	> 1000 ohms	Injector low side - codes 451-458 may be set if shorted to grd.

Under Valve Cover Harness and Injector Solenoid Resistance Checks
(Check with pigtail connector installed on gasket connector)

Test Points	Spec.	Comments
B to C	3.4 ± 2 ohms	Resistance thru injector solenoid and UVC harness - codes 421-428 may be present if open, codes 431-438 may be present if injector or harness shorted together.
C to D	3.4 ± 2 ohms	

Engine Harness to IDM connector checks (measure to appropriate pin)

Test Points	Spec.	Comments
B to IDM	< 5 ohms	Injector low side - code(s) 421-428 present if open present.
C to IDM	< 5 ohms	Injector pwr. feed high side-code(s) 513 or 514 present if open, code 524 indicates sides shorted together.
D to IDM	< 5 ohms	Injector low side - code(s) 421-428 present if open present.

Injector (INJ) Drive Circuit Operation (Cont.)

SYSTEM DESCRIPTION

The engine control system includes an ECM (Electronic Control Module) and an IDM (Injector Drive Module). The ECM provides the IDM with two important output signals which control fuel injector operation. The ECM uses the fuel quantity control strategy and input from the engine sensors to determine how long each fuel injector is actuated in order to provide the proper fuel quantity at any given engine operating condition. The ECM determines and provides a fuel output signal, FDCS (Fuel Demand Command Signal), by combining the desired length of each injection with the result of the injection timing control strategy which determines when each injection will occur. The second output signal, (CI) Cylinder Identification, enables the IDM to determine the correct injector firing order.

The IDM processes the FDCS and CI signals sent by the ECM to control injector operation. It amplifies the FDCS signal to make it powerful enough to operate the injectors and distributes it to each injector according to the CI signal.

OPERATION

The IDM contains two solid state high side drivers. Each driver supplies a continuous 115 volts DC. Right bank high side driver supplies cylinders 1,3,5 and 7 with 115 volts at terminal 24 of the IDM to terminals 3 and 20 of the valve cover connector. Left bank high side driver supplies cylinders 2,4,6 and 8 with 115 volts at terminal 23 of the IDM to terminals 21 and 11 of the valve cover connector. The IDM turns each injector on by switching on a solid state device (Low Side Driver) to ground the injector solenoid return circuit. The IDM contains a low side driver for each of the injectors.

IDM DIAGNOSTICS

The IDM monitors the voltage on the driver circuits and is capable of detecting an open or shorted circuit. If the IDM detects a short to ground or a multiple fault in a driver, the IDM will discontinue operation of that driver which would cause the engine to operate on the remaining bank of 4 cylinders. The IDM will transmit a message to the ECM that a fault has been detected. The ECM will respond by illuminating the Engine Warning Light and compensating for inoperative cylinders to keep the engine running if mechanically possible.

Faults detected by the IDM will be stored in the IDM and transmitted to the ECM during an “Engine Off Standard Test”. These faults will be transmitted as Inactive faults. Faults can be retrieved using the Electronic Service Tool or the STI Self Test Input Diagnostic Switch located on the vehicle dash.

NOTE: *The last digit of the flash code indicates the affected cylinder number. For example, code 421 indicates cylinder no. 1 has an open circuit between the IDM high side driver and the low side (signal return) to the idm. The SID no.s 1-8, indicate cylinder no.s in a similar manner.*

FLASH CODE *421 THROUGH 428*

ATA CODE SID 1 THROUGH 8 FMI 5

HIGH SIDE TO LOW SIDE OPEN

Flash Codes for High Side to Low Side Open indicate an open circuit between the IDM high side driver and the low side (Signal return) to the IDM.

The ECM will compensate for engine misfire to keep the engine operating. The ECM will not illuminate the Engine Warning light when this situation occurs.

Possible causes: Open wire in injector harness, open injector return circuit or injector solenoid.

FLASH CODE *431 THROUGH 438*

ATA CODE SID 1 THROUGH 8 FMI 4

High SIDE SHORTED TO LOW SIDE

Flash codes for High Side Shorted to Low Side indicate the return voltage is too high due to a short circuit between the high side driver and return circuit.

The ECM will compensate for engine misfire to keep the engine operating. The ECM will not illuminate the Engine Warning light when this situation occurs.

Possible causes: Shorted injector solenoid or wiring harness.

FLASH CODE *441 THROUGH 448*

ATA CODE SID 1 THROUGH 8 FMI 3

LOW SIDE SHORTED TO B+

Low Side Shorted to B+ indicates the IDM has detected continuous battery voltage on the signal return circuit.

The ECM will compensate for engine misfire to keep the engine operating. The ECM will not illuminate the Engine Warning light when this situation occurs.

A short circuit in the injector wiring harness will set these codes.

Injector (INJ) Drive Circuit Operation (Cont.)

FLASH CODE *451 THROUGH 458*

ATA CODE SID 1 THROUGH 8 FMI 6

LOW SIDE SHORTED TO GROUND

Flash codes for Low Side Shorted to Ground indicate the return circuit shorted to ground.

If the IDM detects this fault, it will disable the entire bank of cylinders associated with the cylinder indicated.

Possible causes: Shorted injector solenoid or wiring harness to ground.

FLASH CODE *511*

ATA CODE SID 151 FMI 11

BANK 1 HAS MULTIPLE FAULTS

Multiple Faults indicates more than one fault was detected by the IDM, such as an open and a short circuit in cylinders 1,3,5, and 7.

With flash code 511 active, the IDM will disable the drivers for cylinders 1,3,5 and 7. The ECM will compensate for misfire to keep the engine operating and will illuminate the Engine Warning Light.

FLASH CODE *512*

ATA CODE SID 152 FMI 11

BANK 2 HAS MULTIPLE FAULTS

Multiple Faults indicates more than one fault was detected by the IDM, such as an open and a short circuit in cylinders 2,4,6 and 8.

With flash code 512 active, the IDM will disable the drivers for cylinders. 2,4,6 and 8. The ECM will compensate for misfire to keep the engine operating and will illuminate the Engine Warning Light.

FLASH CODE *513*

ATA CODE SID 151 FMI 5

HIGH SIDE OPEN, RIGHT GROUP

With High Side Open Right Group (Bank 1), the IDM has detected an open circuit to the injectors on cylinders 1, 3, 5, or 7.

With flash code 513 active, the drivers for cylinders 1, 3, 5, and 7 are inoperative . The ECM will compensate for misfire to keep the engine operating and will illuminate the Engine Warning light.

FLASH CODE *514*

ATA CODE SID 152 FMI 5

HIGH SIDE open left group

With the High Side Open Left Group (Bank 2), the IDM has detected an open circuit to the injectors on cylinders 2,4,6 and 8.

With flash code 513 active, the drivers for cylinders 2,4,6 and 8 are inoperative . The ECM will compensate for misfire to keep the engine operating and will illuminate the Engine Warning light.

FLASH CODE *515*

ATA CODE SID 151 FMI 6

HIGH SIDE Bank 1 SHORT TO GROUND OR B+

Flash code 515 indicates the IDM has detected the high side driver for cylinders 1, 3, 5 and 7 has excessive current draw.

With flash code 515 active, the driver for cylinders 1, 3, 5 and 7 will be disabled. The ECM will compensate for engine misfire to keep the engine running. This code will cause the Engine Warning light to be illuminated.

FLASH CODE *521*

ATA CODE SID 152 FMI 6

HIGH SIDE BANK 2 SHORT TO GROUND OR B+

Flash code 521 indicates the IDM has detected excessive current draw on high side driver for cylinders 2, 4, 6 and 8.

With flash code 521 active, the driver for cylinders 2, 4, 6 and 8 will be disabled. The ECM will compensate for engine misfire to keep the engine operating and will illuminate the Engine Warning light.

FLASH CODE *524*

ATA CODE SID 151 FMI 3

BOTH HIGH SIDE SWITCHES SHORTED TOGETHER

Flash code 524 indicates a short circuit between the two high side drivers.

With this code active, the Engine Warning light will be illuminated.

Injector (INJ) Drive Circuit Operation (Cont.)

FLASH CODE *544*

ATA CODE SID 152 FMI 14

INJECTOR FAULT BANK #2

Flash code 544 indicates ECM has detected more than one injector in Bank #2 (Left Bank) with low voltage.

FLASH CODE *545*

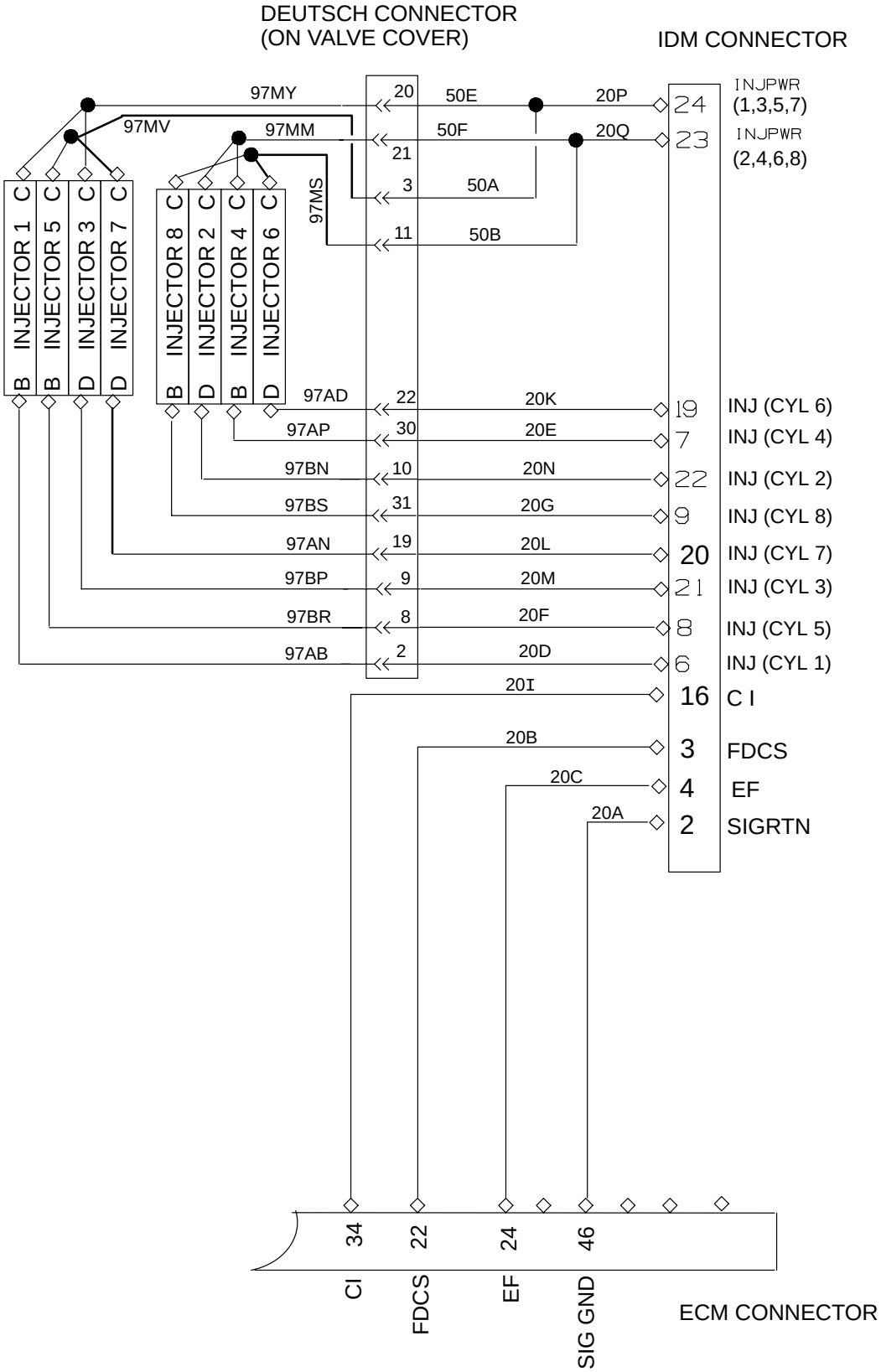
ATA CODE SID 151 FMI 14

INJECTOR FAULT BANK #1

Flash code 545 indicates ECM has detected more than one injector in Bank #1 (Right Bank) with low voltage.

Injector (INJ) Drive Circuit Operation (Cont.)

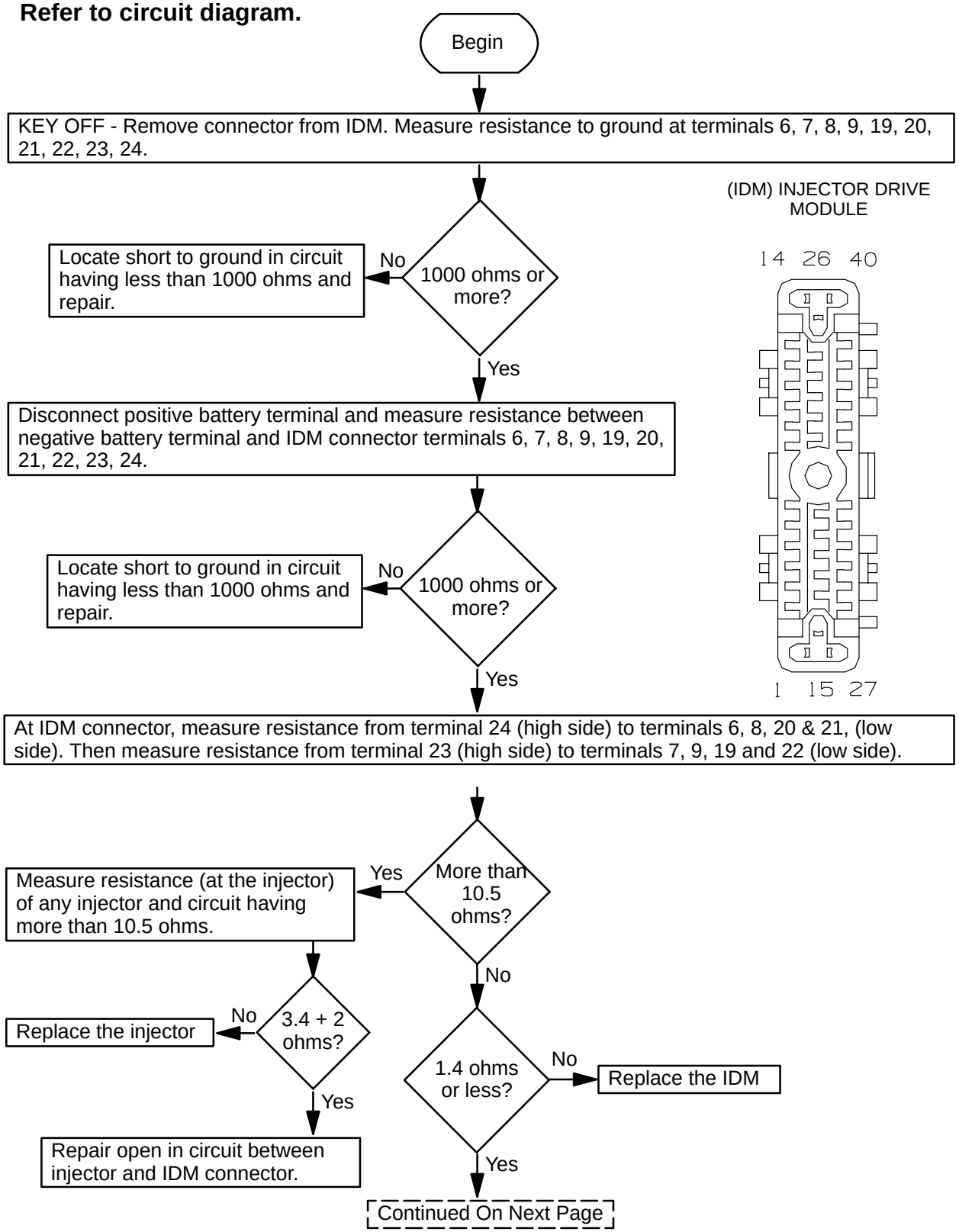
INJECTOR CIRCUIT DIAGRAM



Injector (INJ) Drive Circuit Operation (Cont.)

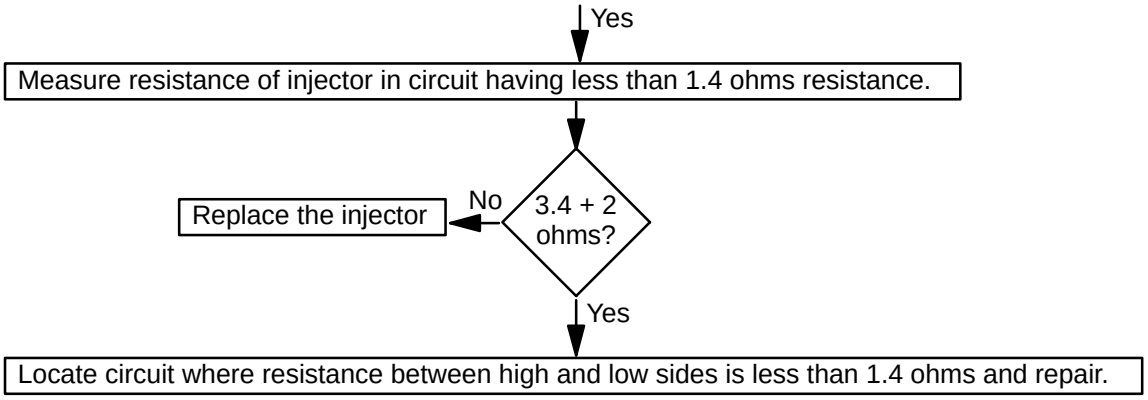
INJECTOR CIRCUIT TESTING

Refer to circuit diagram.

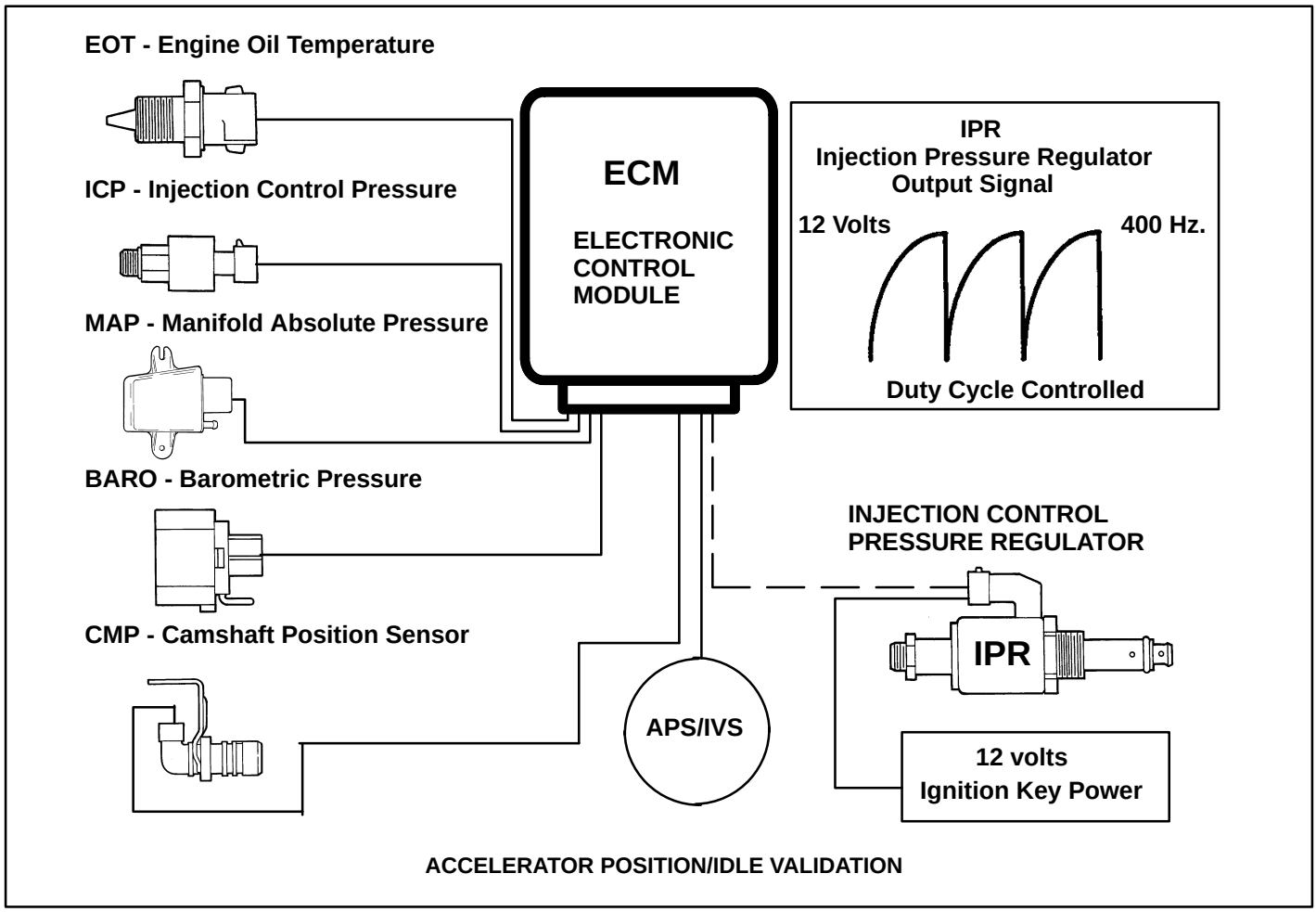

Begin
KEY OFF - Remove connector from IDM. Measure resistance to ground at terminals 6, 7, 8, 9, 19, 20, 21, 22, 23, 24.
1000 ohms or more?
No
Locate short to ground in circuit having less than 1000 ohms and repair.
Yes
Disconnect positive battery terminal and measure resistance between negative battery terminal and IDM connector terminals 6, 7, 8, 9, 19, 20, 21, 22, 23, 24.
1000 ohms or more?
No
Locate short to ground in circuit having less than 1000 ohms and repair.
Yes
At IDM connector, measure resistance from terminal 24 (high side) to terminals 6, 8, 20 & 21, (low side). Then measure resistance from terminal 23 (high side) to terminals 7, 9, 19 and 22 (low side).
More than 10.5 ohms?
Yes
Measure resistance (at the injector) of any injector and circuit having more than 10.5 ohms.
3.4 + 2 ohms?
No
Replace the injector
Yes
Repair open in circuit between injector and IDM connector.
No
1.4 ohms or less?
No
Replace the IDM
Yes
Continued On Next Page
(IDM) INJECTOR DRIVE MODULE
14 26 40
1 15 27

Injector (INJ) Drive Circuit Operation (Cont.)

INJECTOR CIRCUIT TESTING


Yes
Measure resistance of injector in circuit having less than 1.4 ohms resistance.
3.4 + 2 ohms?
No
Replace the injector
Yes
Locate circuit where resistance between high and low sides is less than 1.4 ohms and repair.

Injection Pressure Regulator (IPR)



OUTPUT FUNCTIONS

Injection Pressure Regulator - Is a variable position valve that controls injection control pressure. The ECM uses many input variables to determine the desired injection control pressure.

Battery voltage is supplied to the IPR when the ignition key is in the on position. Valve position is controlled by switching the output signal circuit to ground inside the Electronic Control Module (ECM). On off time is modulated from 0-50% dependent upon the desired injection control pressure.

FAULT DETECTION/MANAGEMENT

An open or a short to ground control circuit can be detected by an on demand output circuit check performed during the engine off test.

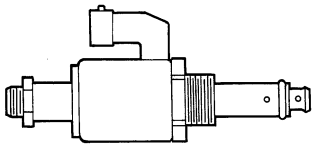
The ECM is capable of detecting, while the engine is running, if desired injection control pressure is equal to measured injection control pressure. If the measured injection control pressure does not reasonably compare to the desired injection control pressure, the ECM ignores the measured ICP signal and attempts to control the engine with the desired value. (If the problem was in the sensor circuit, this strategy causes little performance deterioration, if the problem is in the control circuit, engine performance will probably still be unsatisfactory).

A faulty IPR or problem with the high pressure oil system can be detected by the engine running test during the injection control pressure step test. During this test, the ECM commands and measures two specific pre programmed pressures. A fault code is set, if the pressures can not be maintained.

NOTE: *The engine will not operate with an IPR circuit that is not functioning.*

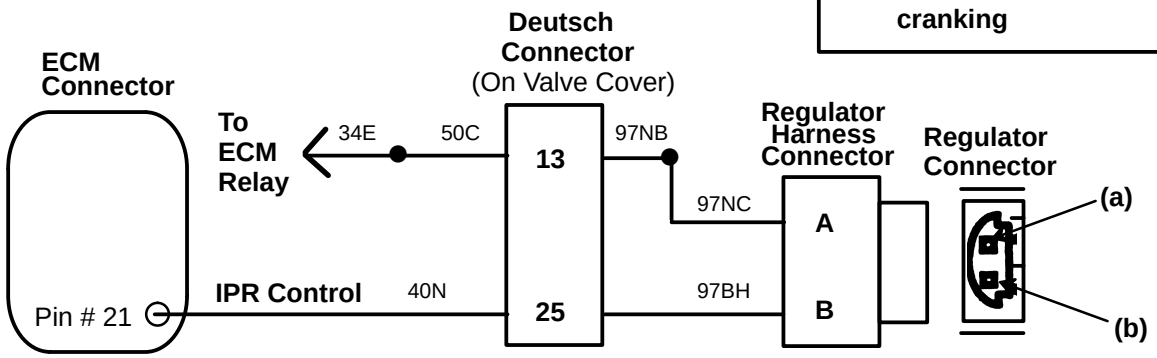
Injection Pressure Regulator (IPR) - Cont.

Injection Pressure Regulator (IPR)



Fault Codes:

241 Output Circuit Check
331 Excessive ICP Pressure
333 In-Range Fault
334 Unable to reach setpoint
335 Unable to build ICP during cranking



After removing connectors always check for damaged pins, corrosion, loose terminals etc.

Connector Checks to Ground (B-)
(Check with IPR Connector Disconnected and Ignition key off, all accessories off)

Test Points	Spec.	Comments
B to Grd.	> 1000 ohms	A short to ground will command full IPR pressure, code 331 may be set.

IPR Voltage Check
(Check with regulator connector disconnected)

Test Points	Spec.	Comments
A to Grd.	B+	Battery voltage from F2, check with key on (GP relay coil is supplied from same fuse).
B to Grd.	0 - .25v	If greater than .25 volts, signal wire is shorted to V Ref. or battery.

Harness Resistance Checks
(Check with breakout box installed & IPR connector reconnected.)

Test Points	Spec.	Comments
#21 to 30 Amp	5 to 20 ohms	Resistance through entire IPR circuit including regulator, check with regulator connector connected.
#21 to B	< 5 ohms	Resistance from 60 pin connector to regulator connector.
30 Amp to A	< 5 ohms	Resistance from power supply to regulator connector.

Fault Code Descriptions

241= Output circuit check detected during Std. test, indicates high or low resistance in circuit.

331 = ICP pressure was greater than 3675 PSI (25 MPa) for 1.5 seconds. (Possible grounded IPR control circuit.) (Refer to injection control pressure diagnostics if not electronic fault.)

333/334 = (1) If set during normal engine operation indicates engine is operating in open loop control and ICP pressure is above or below desired pressure. (Refer to ICP control system diagnostics.)

(2) If set during engine running test, indicates ICP system failed step test and could not maintain commanded pressure.

335 = ICP unable to build pressure during cranking.

Injection Pressure Regulator (IPR) - Cont.

FUNCTION

The engine control system includes a Injection Pressure Regulator (IPR) valve that controls oil pressure in the high pressure injection control system which is used to actuate the injectors. The IPR valve consists of a solenoid, poppet and spool valve assembly and is mounted in the high pressure oil pump. The ECM regulates injection control pressure by controlling the duty cycle or (on/off time) of the injection control pressure solenoid. This increase or decrease of "on/off" time positions a poppet valve and spool valve internal to the IPR, which in turn either maintains pressure in the injection control pressure system or vents pressure to the oil sump via the front cover.

OPERATION

The IPR valve is supplied with voltage at terminal "A" of the IPR connector when the ignition key is turned on. Control of the injection control system is accomplished by the ECM grounding the IPR circuit from terminal "B" of the IPR valve thru pin #21 of the ECM. Precise control is accomplished by varying the pulse width or percentage of "on/off" time of the IPR solenoid. The frequency of the pulsewidth to the IPR is 400 Hz, normal "on/off" times varies from 8% to 50%. A high duty cycle indicates a high amount of injection control pressure being commanded, a low duty cycle is an indication of less pressure being commanded.

ECM DIAGNOSTICS

The ECM monitors the Injection Control Pressure while the engine is in operation. If the actual pressure is greater or less than the desired pressure, the ECM will set a fault code. When this occurs, the ECM will ignore the ICP sensor and control the engine using pre-programmed values for the IPR.

The Electronic Service Tool is used to Perform the Engine Running Standard Test which enables the ECM to vary the command signal to the IPR and monitor the performance of the Injection Control Pressure system. If the system does not respond within the specified parameters, the ECM will set a fault code.

Fault codes can be retrieved using the Electronic Service Tool or the Self Test Input diagnostic switch located on the vehicle dash. If the ignition key is shut off, the code will be stored as an Inactive code.

FLASH CODE *241*

ATA CODE SID 42 FMI 11

INJECTION CONTROL PRESSure REG. OCC SELF TEST FAILED

Code 241 is set only during the Engine Off Standard Output Circuit Check. This test indicates the ECM has performed an output circuit test, measured voltage drop across the IPR circuit and determined it is below or above specification.

If this fault is present, the engine will not run. The ECM will not illuminate the Engine Warning light if this code is active, however, this code will be transmitted at the completion of the Output Circuit Check, using the STI switch or the Electronic Service Tool.

Possible causes: Open feed circuit or fuse to the IPR, open IPR solenoid, or an open or shorted IPR signal circuit.

FLASH CODE *331*

ATA CODE PID 164 FMI 0

INJECTION CONTROL PRESSURE ABOVE SYSTEM WORKING RANGE

Code 331 indicates the ECM has detected injection control pressure greater than 3675 PSI (25 MPA) which is greater than the maximum allowable working pressure.

When this code is active, the ECM will illuminate the Engine Warning light.

Possible causes: Incorrect ICP signal due to faulty circuits or sensor, grounded IPR signal circuit, a malfunction in the injection control pressure system or a sticking or blocked IPR valve. Refer to Injection Control Pressure system diagnostics.

Injection Pressure Regulator (IPR) - Cont.

FLASH CODE *333*
ATA CODE PID 164 FMI 10
INJECTION CONTROL PRESSURE ABOVE/BELOW DESIRED LEVEL

Code 333 may be set during normal engine operation through the continuous monitor function or during the Engine Running Standard Test. It indicates the measured pressure does not match the expected value. The ECM will illuminate the Engine Warning light.

When this code is active, the ECM will ignore the ICP sensor signal and will control the IPR from programmed values to keep the engine operating. Perform ICP sensor diagnostics to determine if the problem exists in the ICP sensor/circuit. If diagnostic testing indicates the ICP sensor/circuit is functioning properly, perform additional diagnostic tests on the injection control pressure system. Refer to Injection Control Pressure system diagnostics.

Possible causes: Incorrect ICP signal due to circuit or sensor malfunctions. IPR signal circuit may be grounded or contain excessive resistance. The IPR valve may be sticking or blocked. Injection control pressure system may not be functioning properly.

FLASH CODE *334*
ATA CODE PID 164 FMI 7
INJECTION CONTROL PRESSURE UNABLE TO REACH SETPOINT-POOR PERFORMANCE

Code 334 indicates an injection control system response time fault and may be set during normal engine operation through the continuous monitor function or during the Engine Running Standard Test.

While the driver rapidly accelerates, the ECM compares the actual vs. the desired injection control pressure and looks for a large pressure difference (1300 PSI/9MPA) for a short period of time (3 seconds). If the injection control system does not respond quick enough Code 334 will be set and the Engine Warning Lamp will be illuminated.

Possible Causes: Low oil level, contaminated engine oil or aerated oil. Trapped air in the injection control pressure system (particularly after an injector or high pressure pump replacement). Defective or stuck Injection Pressure Regulator (IPR). Intermittent IPR valve wiring connection-spread IPR harness terminals at IPR valve, poorly crimped terminals or pulled back pin. Leaking injector O-rings. Problem with ICP sensor and sensor circuit, system biased high or low. Refer to Injection Control Pressure system diagnostics in.

FLASH CODE *335*
ATA CODE PID 164 FMI 1
INJECTION CONTROL PRESSURE UNABLE TO BUILD PRESSURE DURING CRANKING

Code 335 indicates the ECM has determined that the injection control pressure system has failed to build a pressure of at least 725 PSI/(5 MPA) during a programmed period of engine cranking time which will vary with engine temperature.

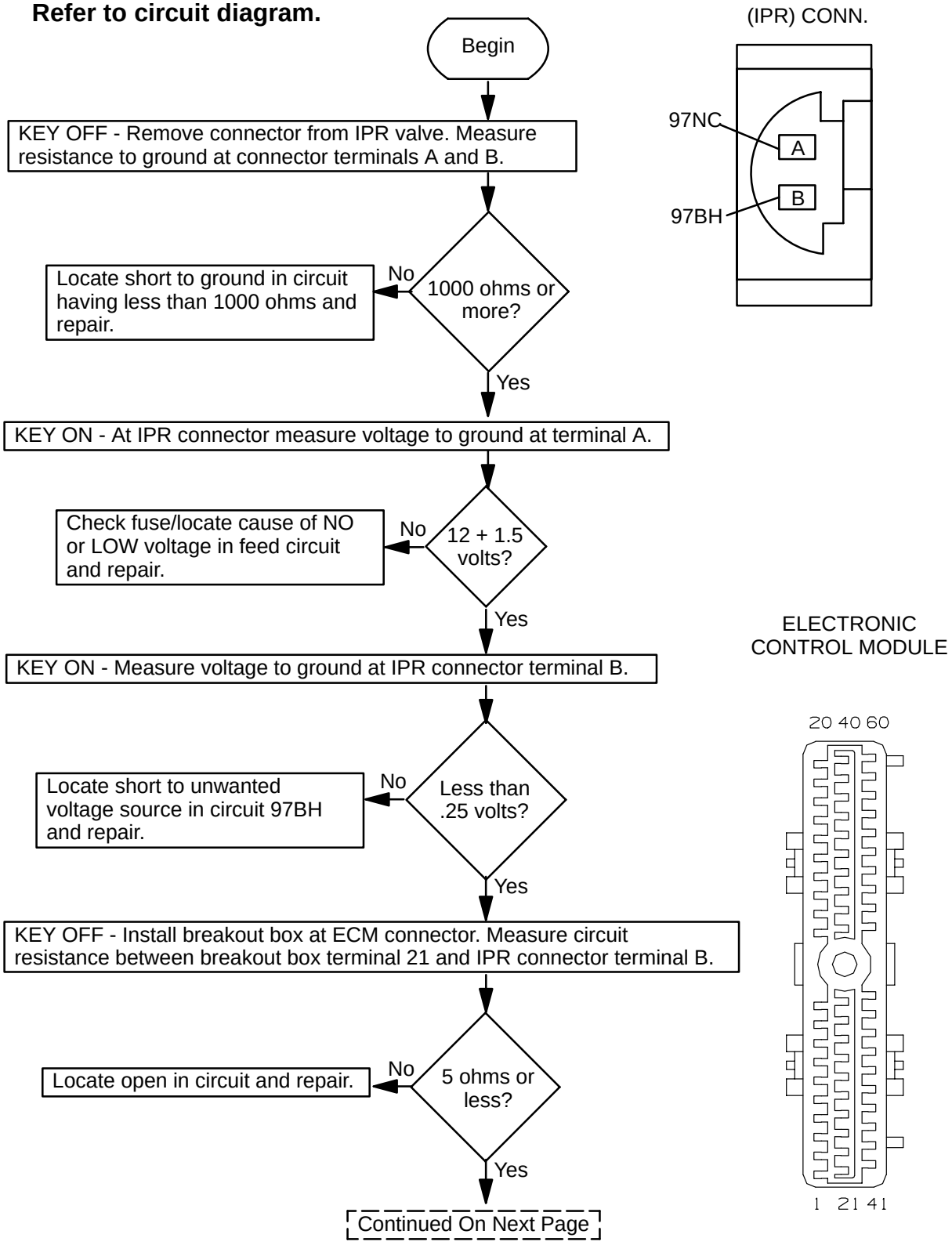
NOTE: *Engine cranking speed must be greater than 130 RPM before fault detection begins.*

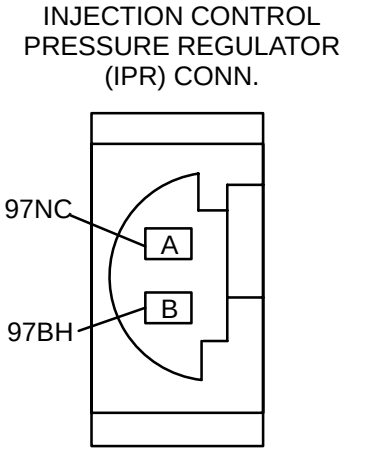
Possible Causes: No oil in engine. Air in the injection control pressure system (particularly after an injector or high pressure pump replacement). Defective or stuck IPR regulator. Leaking injector O-rings. Loose high pressure pump gear. Defective high pressure oil pump.

Injection Pressure Regulator (IPR) - Cont.

INJECTION CONTROL PRESSURE REGULATOR TESTING

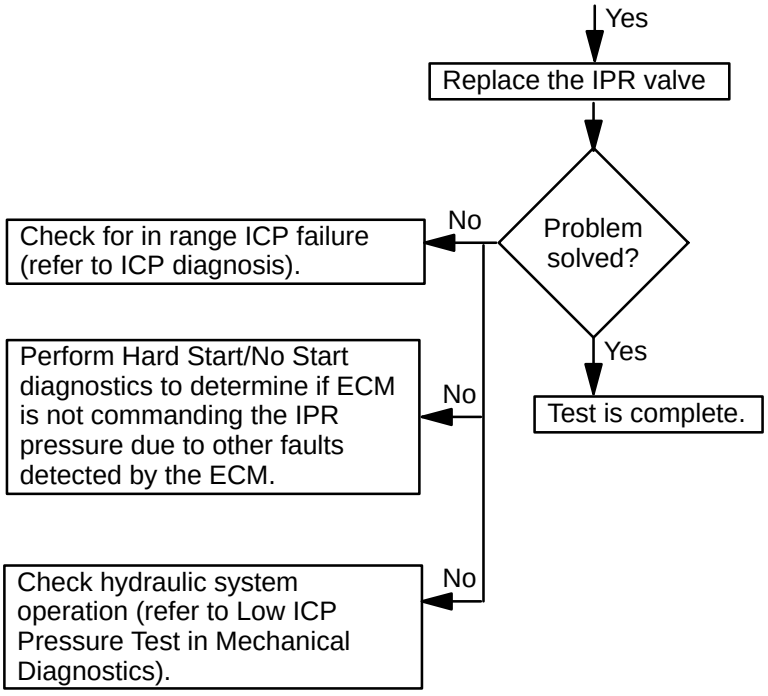
Refer to circuit diagram.


Begin
KEY OFF - Remove connector from IPR valve. Measure resistance to ground at connector terminals A and B.
1000 ohms or more?
No
Locate short to ground in circuit having less than 1000 ohms and repair.
Yes
KEY ON - At IPR connector measure voltage to ground at terminal A.
12 + 1.5 volts?
No
Check fuse/locate cause of NO or LOW voltage in feed circuit and repair.
Yes
KEY ON - Measure voltage to ground at IPR connector terminal B.
Less than .25 volts?
No
Locate short to unwanted voltage source in circuit 97BH and repair.
Yes
KEY OFF - Install breakout box at ECM connector. Measure circuit resistance between breakout box terminal 21 and IPR connector terminal B.
5 ohms or less?
No
Locate open in circuit and repair.
Yes
Continued On Next Page

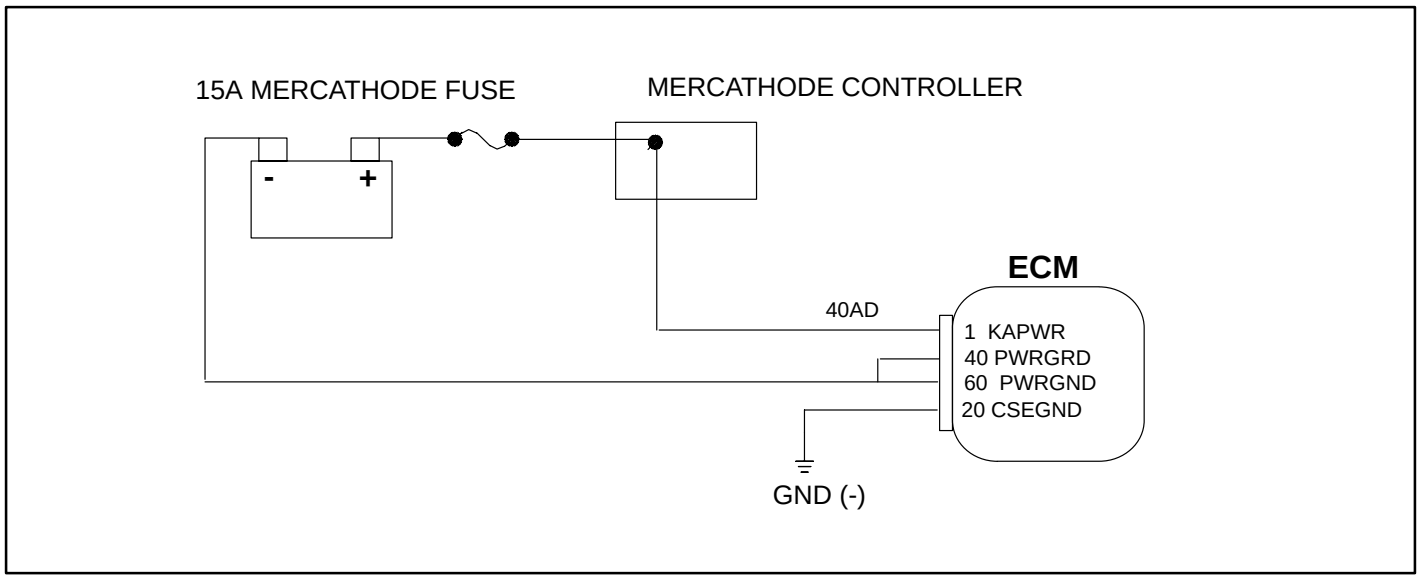


Injection Pressure Regulator (IPR) - Cont.

INJECTION CONTROL PRESSURE REGULATOR TESTING


Yes
Replace the IPR valve
Problem solved?
No
Check for in range ICP failure (refer to ICP diagnosis).
Yes
Test is complete.
Perform Hard Start/No Start diagnostics to determine if ECM is not commanding the IPR pressure due to other faults detected by the ECM.
No
Check hydraulic system operation (refer to Low ICP Pressure Test in Mechanical Diagnostics).
No

Keep Alive Memory Power (KAM PWR)



CIRCUIT OPERATION

The Electronic Control Module (ECM) has information stored in volatile memory which is erased or lost when power is disconnected from the module. This memory is referred to as Keep Alive Memory (KAM). The ECM stores historical diagnostic information from previous engine operating cycles, learned limits from certain engine sensors and programmable parameters sent from the VPM.

The Vessel Personality Module (VPM) utilizes the KAM power circuit to remain powered for at least 30 minutes after each key off cycle to record accumulator values for hours and fuel used.

FAULT DETECTION MANAGEMENT

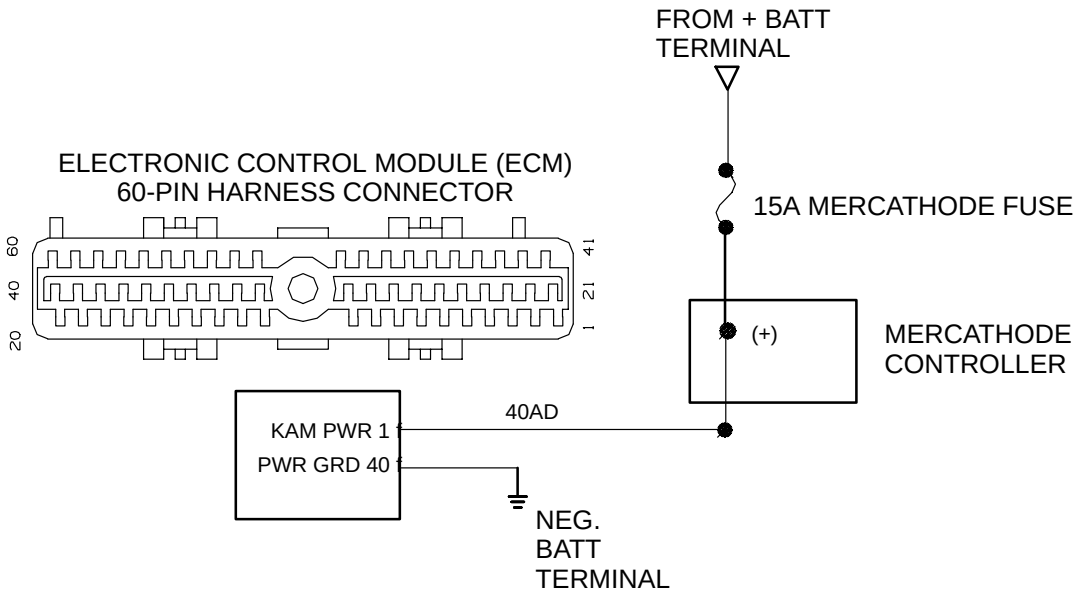
On every power up KAM memory in the ECM is checked by the processor to determine if any information in memory has been lost or can be stored correctly. A fault code will be set if power has been disconnected, information sent from the VPM does not agree with the last power up or if the memory internal to the ECM is defective.

There is no fault detection for loss of KAM power to the the VPM, however, the VPM will be unable to communicate with the Electronic Service Tool (EST) when the ignition key is in the OFF position.

Keep Alive Memory Power (KAM PWR) Cont.

Keep Alive Memory Power (KAM PWR)

Fault Codes:
224 KAM Corrupt
615 Programmable Parameter KAM Corrupt



KAMPWR to ECM - Connector (379) with breakout box installed and key OFF

Test Points	Spec.	Comments
#1 to grd.	12 ± 1.5 volts	< than 10.5 v check connections, if 0 volts check for open/short to ground or blown fuse (If fuse is open the ECM will not be powered with key ON and Prolink will not read codes)
#1 to #40	12 ± 1.5 volts	< than 10.5 v check connections, if 0 volts check for open in ground path.

NOTE: If the KAM PWR to the ECM is good and ground circuits are good, and Flash code 224 or 615 remains active, the ECM is defective.

Fault Code Descriptions

224 Kam Memory
615 Programmable Parameter KAM Corrupt Memory Information

Keep Alive Memory Power (KAM PWR) - Cont.

EXTENDED SYSTEM DESCRIPTION

Refer to circuit diagram for the following discussion.

The ECM Keep Alive Memory (KAM) circuit 40AD provides battery power from the Positive battery terminal through ECM connector to ECM terminal 1 at all times. KAM stores fault codes and operating constants between engine starts.

ECM DIAGNOSTICS

During normal operation, the ECM performs certain tests. When the key is turned ON, the ECM performs the Start-Up KAM Test to test its Keep-Alive Memory. The test is performed once each time the key is turned on or when the ECM resets.

The ECM performs a test to determine if the memory is working properly, but a lack of battery power to ECM terminal 1 can cause fault code(s) 224 and 653 to be set.

When power to KAM has been disrupted, there will be no inactive faults.

FLASH CODE 224

SID 254 FMI 2

ECM: *KAM CORRUPT*

Flash Code 224 can be caused by:

1. Short or open in KAM circuit. High or low voltage to ECM terminal 1 from the KAM battery supply circuits will cause code 224.

NOTE: *If the battery cable has been disconnected, on the next key ON cycle, code 224 will be present, indicating that the KAM memory has lost power. The code will change to inactive status on the next key cycle.*

2. Faulty KAM memory in the ECM.

Conditions causing Flash Code 224 can also cause Flash Code 615 to occur.

FLASH CODE 615

SID 254 FMI 13

ECM: *PROGRAMMABLE PARAMETER KAM CORRUPT FAULT*

If flash code 615 occurs when the KAM power supply to the ECM is good, then the KAM memory is defective. Refer to Electronic Control Module Diagnostics (ECM) in this manual section.

TROUBLESHOOTING

BEFORE TROUBLESHOOTING

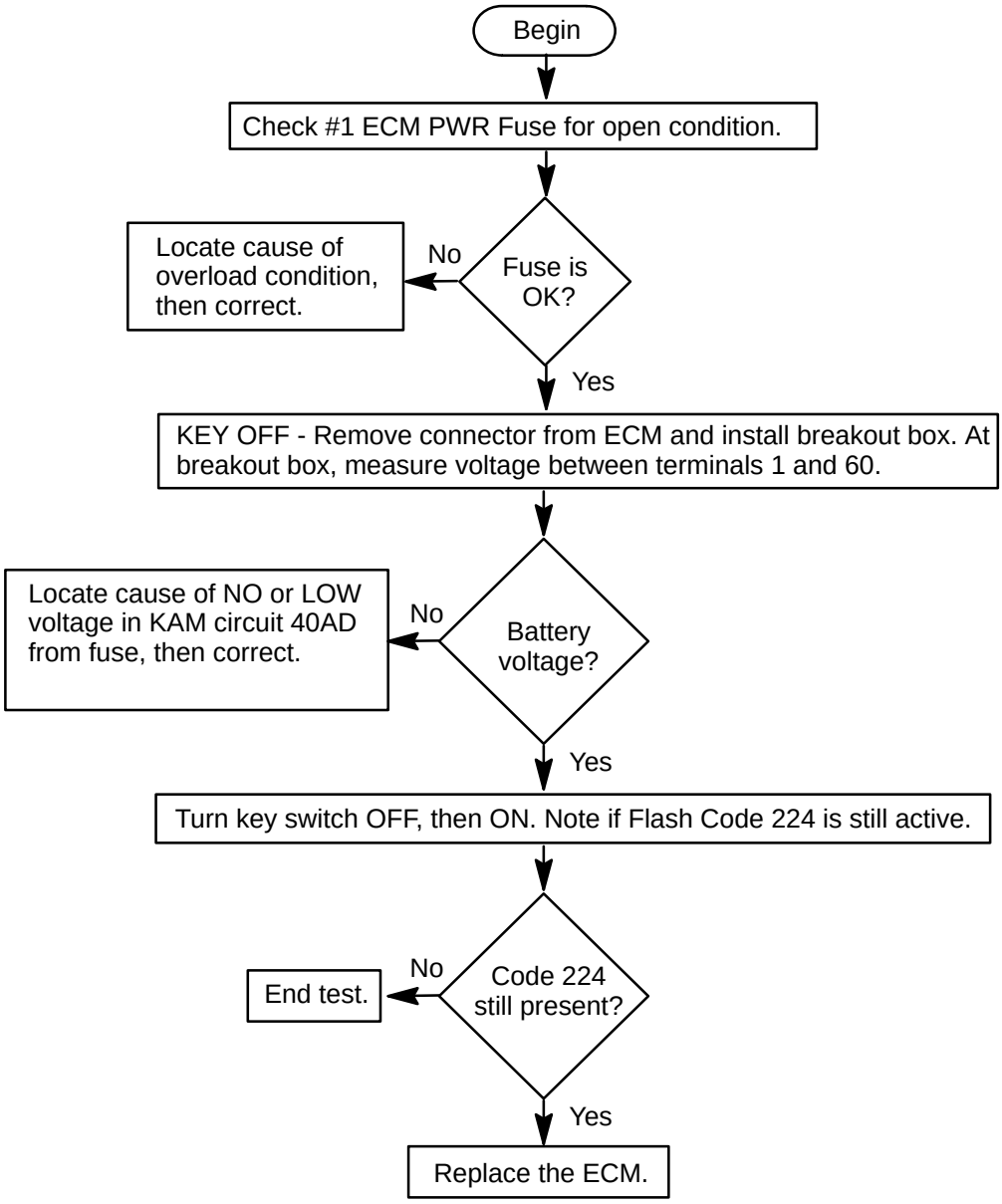
1. Before troubleshooting, make sure that the batteries are fully charged! Check battery connections and grounds for clean, tight connections free of damage. Voltage tests will give mis-leading readings if batteries are not fully charged.
2. Before troubleshooting a particular circuit, inspect connectors for pushed back, loose or damaged (spread or bent) terminals, or wires with cut strands, etc. The wires and connections must be free of damage or corrosion. When some connectors corrode, a light white residue will be present that must be removed.
3. Before troubleshooting, inspect the suspect circuit grounds for clean, tight connections, free of damage or corrosion.

If Flash code 224 or 653 is active, perform KAM Power Circuit.

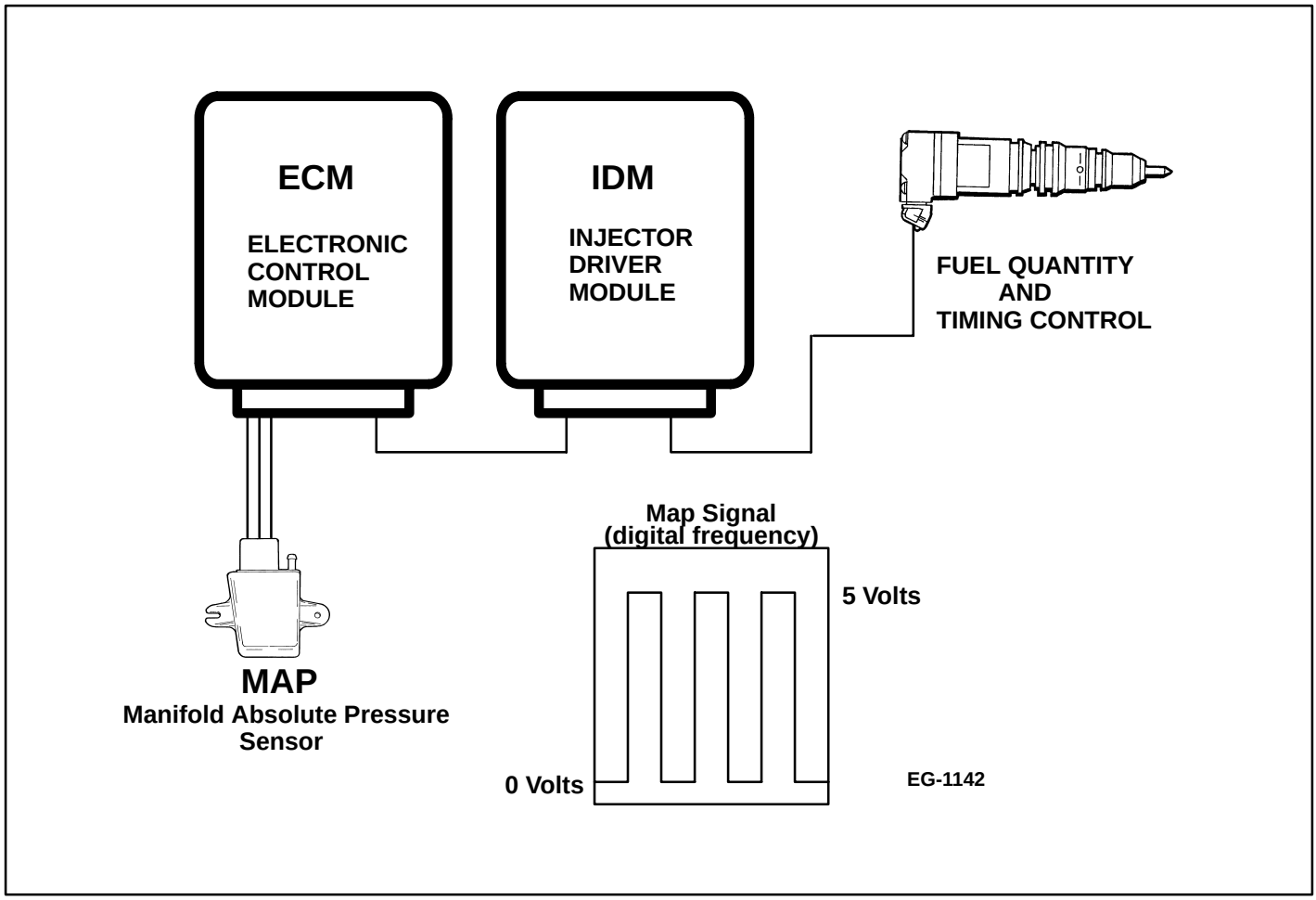
Keep Alive Memory Power (KAM PWR) - Cont.

If the ECM is powered, the fuse does not need to be checked as the same fuse feeds the ECM.

KAM POWER CIRCUIT TEST


Begin
Check #1 ECM PWR Fuse for open condition.
Fuse is OK?
No
Locate cause of overload condition, then correct.
Yes
KEY OFF - Remove connector from ECM and install breakout box. At breakout box, measure voltage between terminals 1 and 60.
Battery voltage?
No
Locate cause of NO or LOW voltage in KAM circuit 40AD from fuse, then correct.
Yes
Turn key switch OFF, then ON. Note if Flash Code 224 is still active.
Code 224 still present?
No
End test.
Yes
Replace the ECM.

Manifold Absolute Pressure (MAP) Sensor



SIGNAL FUNCTIONS

The Manifold Absolute Pressure (MAP) sensor is a variable capacitance sensor which operates on a 5 volt reference signal from the ECM to produce a digital frequency signal that indicates pressure.

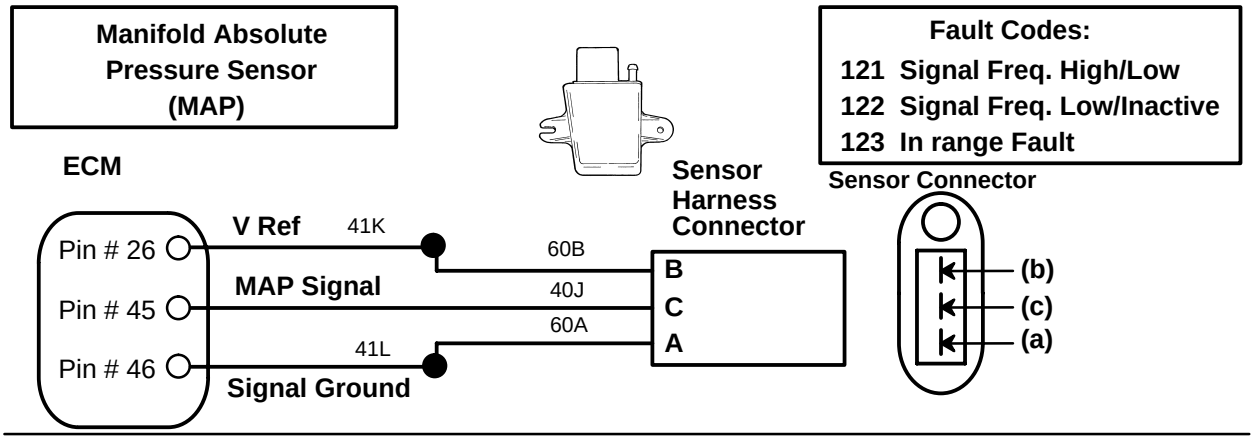
Smoke Control - The MAP signal is used to control smoke by limiting fuel quantity during acceleration until a specified boost pressure is obtained.

Dynamic Injection Timing - Optimizes injection timing for boost pressure measured.

FAULT DETECTION/MANAGEMENT

A MAP signal that is detected by the ECM to be out of range or at an incorrect value for specific conditions will cause the ECM to ignore the MAP signal and will operate the engine with the values from estimated MAP (Operate from a calculated boost pressure signal).

Manifold Absolute Pressure (MAP) Sensor (Cont.)



After removing connectors always check for damaged pins, corrosion, loose terminals etc.

Connector Checks to Ground
(Check with sensor Connector Disconnected and Ignition key off, all accessories off)

Test Points	Spec.	Comments
A to Grd.	< 5 ohms	Resistance to ground check with key off, if > than 5 ohms harness is open.
B to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.
C to Grd.	> 1000 ohms	Resistance less than 1000 ohms indicates a short to ground.

Connector Voltage Checks
(Check with sensor Connector Disconnected and Ignition Key On)

Test Points	Spec.	Comments
B to Grd.	5 volts ± .5	V Ref. check with key ON, if voltage not in spec, see V REF circuit.
C to Grd.	4.8 - 5.0 v	Pull up voltage, if no or low voltage circuit has open or high resistance or short to grd.

Harness Resistance Checks
(Check with breakout box installed on engine harness only)

Test Points	Spec.	Comments
#46 to A	< 5 ohms	Resistance from sensor connector to 60 pin connector - Signal ground
#26 to B	< 5 ohms	Resistance from sensor connector to 60 pin connector - V Ref
#45 to C	< 5 ohms	Resistance from sensor connector to 60 pin connector - MAP signal

Operational Voltage Checks
(Check with breakout box installed in line with the ECM)

Test Points (+) #45 to (-) #46			
Frequency	PSI	kPAG	Comments
90 Hz.	N/A	N/A	Out of range low limit.
108-114 Hz.	0	0	Freq. with key on engine off, Atmospheric pressure dependent on altitude and BARO psi.
145 Hz.	25.4	175	Frequency expected at 25 psi.
256 Hz.	45	267	Out of range high limit

Fault Code Descriptions

Circuit Faults:

121 = Signal frequency was greater than 256 Hz. for more than 0.1 seconds.

122 = Signal frequency was less than 90 Hz. or inactive for more than 0.25 seconds.

System Faults:

123 = Detected high boost signal at low idle. (Restricted MAP line.)

Manifold Absolute Pressure (MAP) Sensor (Cont.)

FUNCTION

The engine control system includes a Manifold Absolute Pressure (MAP) sensor. The ECM measures the signal from the MAP sensor to determine intake manifold (Boost) pressure. From this information, the ECM can optimize control of fuel rate and injection timing for all engine operating conditions.

OPERATION

The Manifold Absolute Pressure sensor is a variable capacitance sensor that produces a digital frequency signal output. The MAP sensor is supplied 5 volts from the ECM at terminal 26 to terminal "B" of the sensor. A return circuit (ground) is supplied from ECM terminal 46 to terminal "A" of the sensor. The sensor receives intake manifold boost pressure via a hose which connects to a tap on the intake manifold to the map sensor. Pressure applied to the MAP sensor changes the capacitance of the sensor which varies the digital frequency of the signal sent to the ECM. As boost pressure increases the frequency increases.

ECM DIAGNOSTICS

The ECM monitors the MAP sensor output signal for expected values. If the ECM detects the MAP signal is greater than or less than the desired value, the ECM will set a fault code.

If an active MAP sensor fault code is set, the ECM will ignore the MAP signal. It will operate the engine using programmed default values. Active faults for the MAP sensor will cause the ECM to illuminate the Engine Warning light. These faults can be retrieved using the Self Test Input diagnostic switch located on the vehicle dash or the Electronic Service Tool. If the ignition key is turned off, the fault code will be stored as an Inactive code.

FLASH CODE *121*

ATA CODE PID 102 FMI 8

MAP FREQUENCY OUT OF RANGE HIGH

Code 121 will be set, if the ECM detects a frequency greater than 256 Hz for more than 0.1 seconds in the MAP signal.

If code 121 is active, the ECM will ignore the MAP signal and operate the engine using programmed default values. The ECM will illuminate the Engine Warning light when this code is active.

Excessive high frequency noise in the MAP signal will cause this code to be set.

FLASH CODE *122*

ATA CODE PID 102 FMI 11

MAP SIGNAL IS INACTIVE

Code 122 will be set, if the ECM detects a frequency less than 90 Hz or an inactive MAP signal for more than 0.25 seconds.

When code 122 is active, the ECM will ignore the MAP signal and operate the engine using programmed default values. The ECM will illuminate the Engine Warning light when this code is set.

Possible causes: A defective MAP sensor or MAP sensor signal circuits may be open or shorted to ground.

FLASH CODE *123*

ATA CODE PID 102 FMI 2

MAP SIGNAL ABOVE SPECIFIED LEVEL AT LOW IDLE

Code 123 is set when the MAP signal is greater than 16.7 PSI (115 kPa) Absolute at low idle.

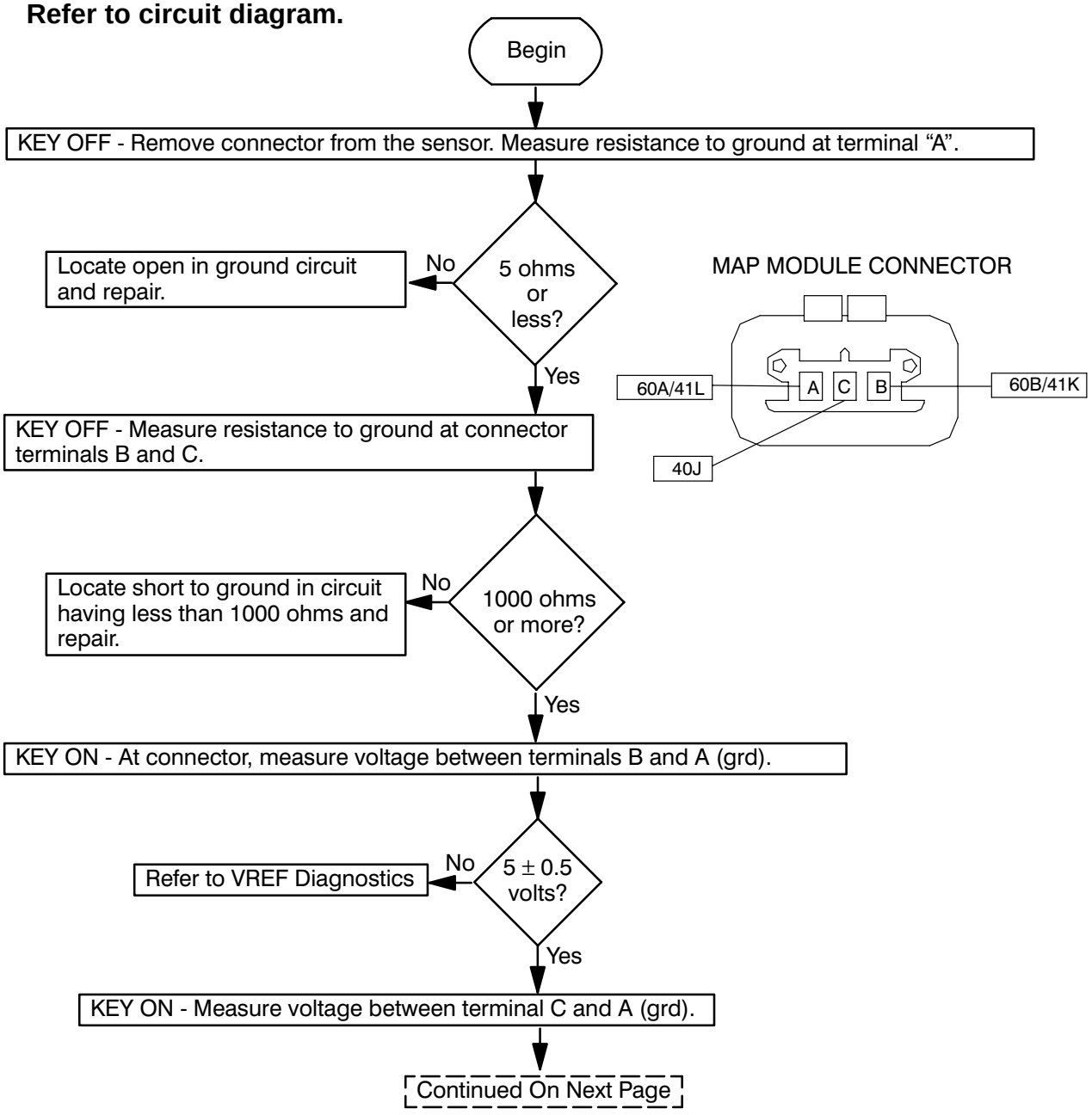
When code 123 is active, the ECM will ignore the MAP signal and operate the engine using programmed default values. The ECM will illuminate the Engine Warning light when this code is set.

Possible causes: Restricted or plugged hose which supplies intake manifold boost pressure to the MAP sensor or a defective MAP sensor.

Manifold Absolute Pressure (MAP) Sensor (Cont.)

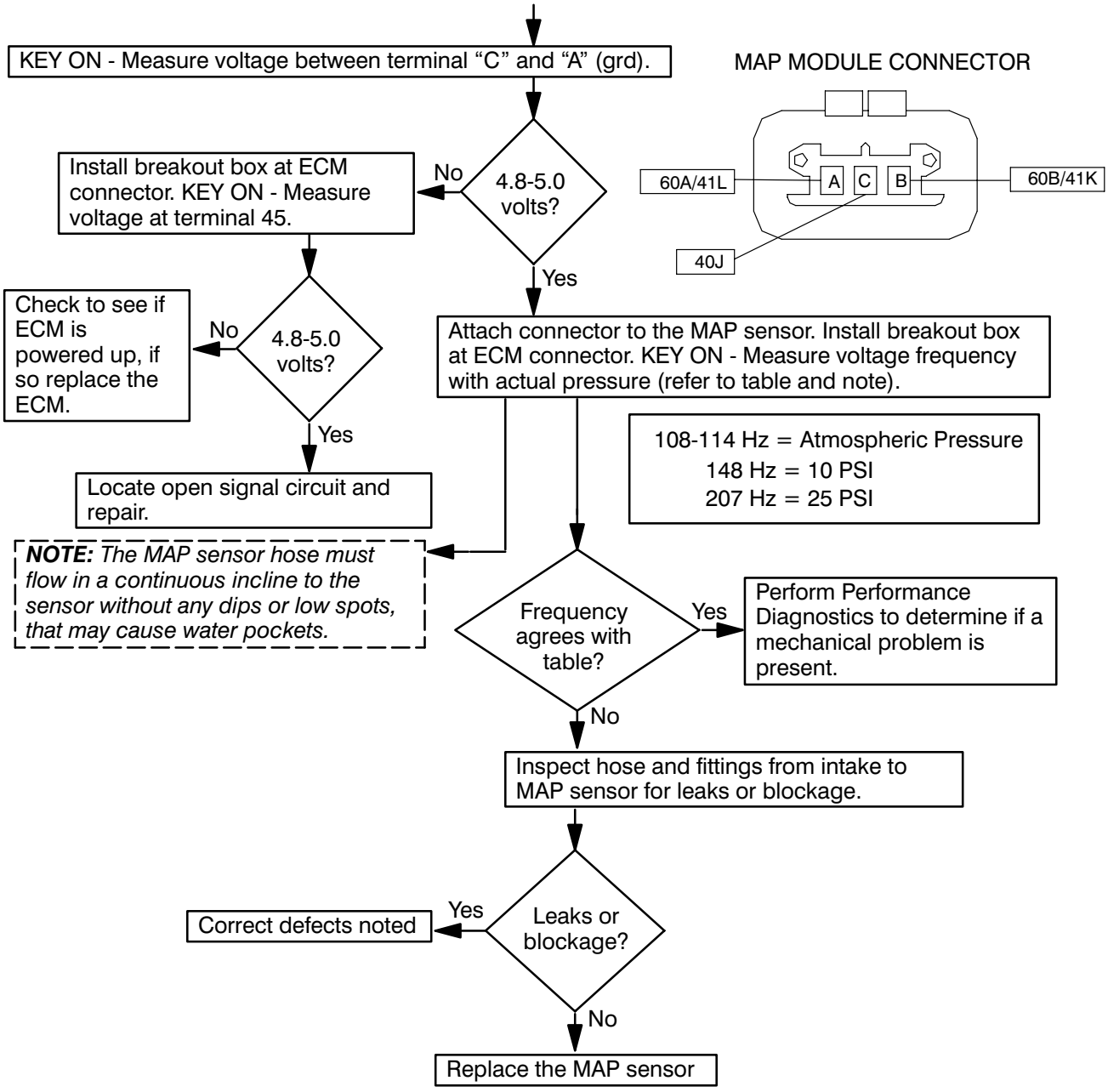
MAP SENSOR CIRCUIT TEST

Refer to circuit diagram.


Begin
KEY OFF - Remove connector from the sensor. Measure resistance to ground at terminal “A”.
5 ohms or less?
No
Locate open in ground circuit and repair.
Yes
KEY OFF - Measure resistance to ground at connector terminals B and C.
1000 ohms or more?
No
Locate short to ground in circuit having less than 1000 ohms and repair.
Yes
KEY ON - At connector, measure voltage between terminals B and A (grd).
5 ± 0.5 volts?
No
Refer to VREF Diagnostics
Yes
KEY ON - Measure voltage between terminal C and A (grd).
Continued On Next Page
MAP MODULE CONNECTOR
60A/41L
A
C
B
60B/41K
40J

Manifold Absolute Pressure (MAP) Sensor (Cont.)

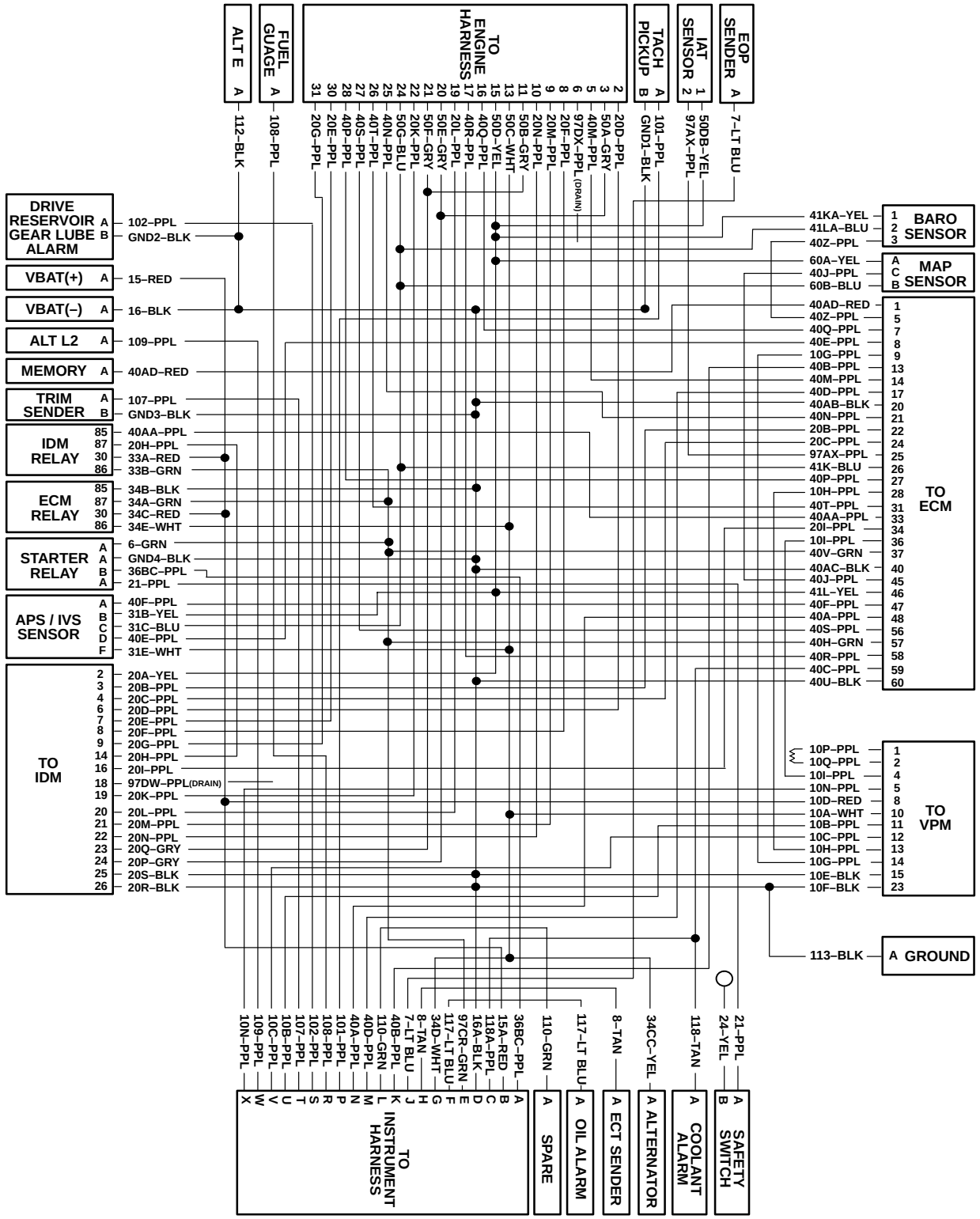
MAP SENSOR CIRCUIT TEST


KEY ON - Measure voltage between terminal “C” and “A” (grd).
4.8-5.0 volts?
No
Install breakout box at ECM connector. KEY ON - Measure voltage at terminal 45.
4.8-5.0 volts?
No
Check to see if ECM is powered up, if so replace the ECM.
Yes
Locate open signal circuit and repair.
Yes
Attach connector to the MAP sensor. Install breakout box at ECM connector. KEY ON - Measure voltage frequency with actual pressure (refer to table and note).
MAP MODULE CONNECTOR
60A/41L
A
C
B
60B/41K
40J
108-114 Hz = Atmospheric Pressure
148 Hz = 10 PSI
207 Hz = 25 PSI
NOTE: The MAP sensor hose must flow in a continuous incline to the sensor without any dips or low spots, that may cause water pockets.
Frequency agrees with table?
Yes
Perform Performance Diagnostics to determine if a mechanical problem is present.
No
Inspect hose and fittings from intake to MAP sensor for leaks or blockage.
Leaks or blockage?
Yes
Correct defects noted
No
Replace the MAP sensor

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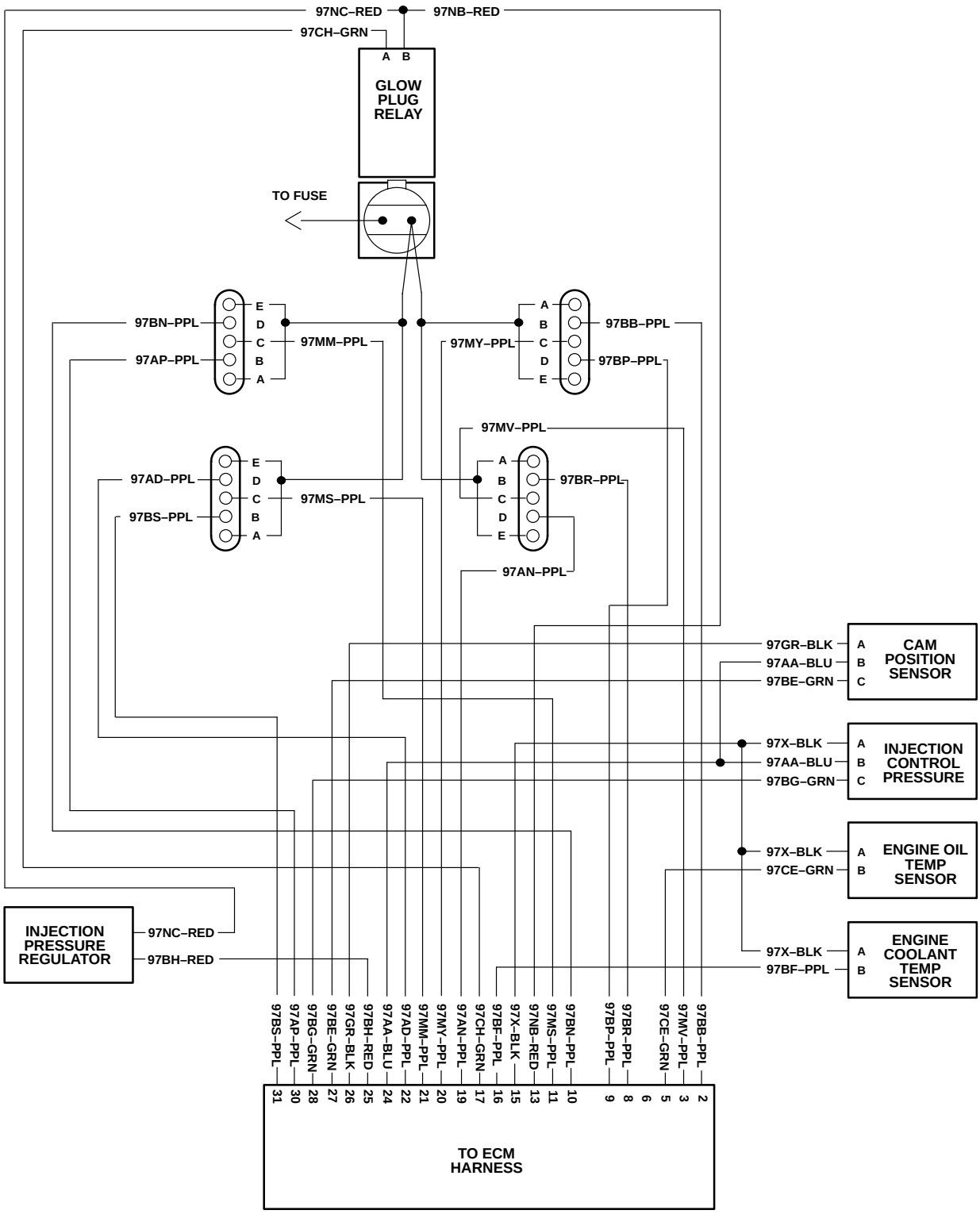
Wiring Diagrams

ECM System Harness



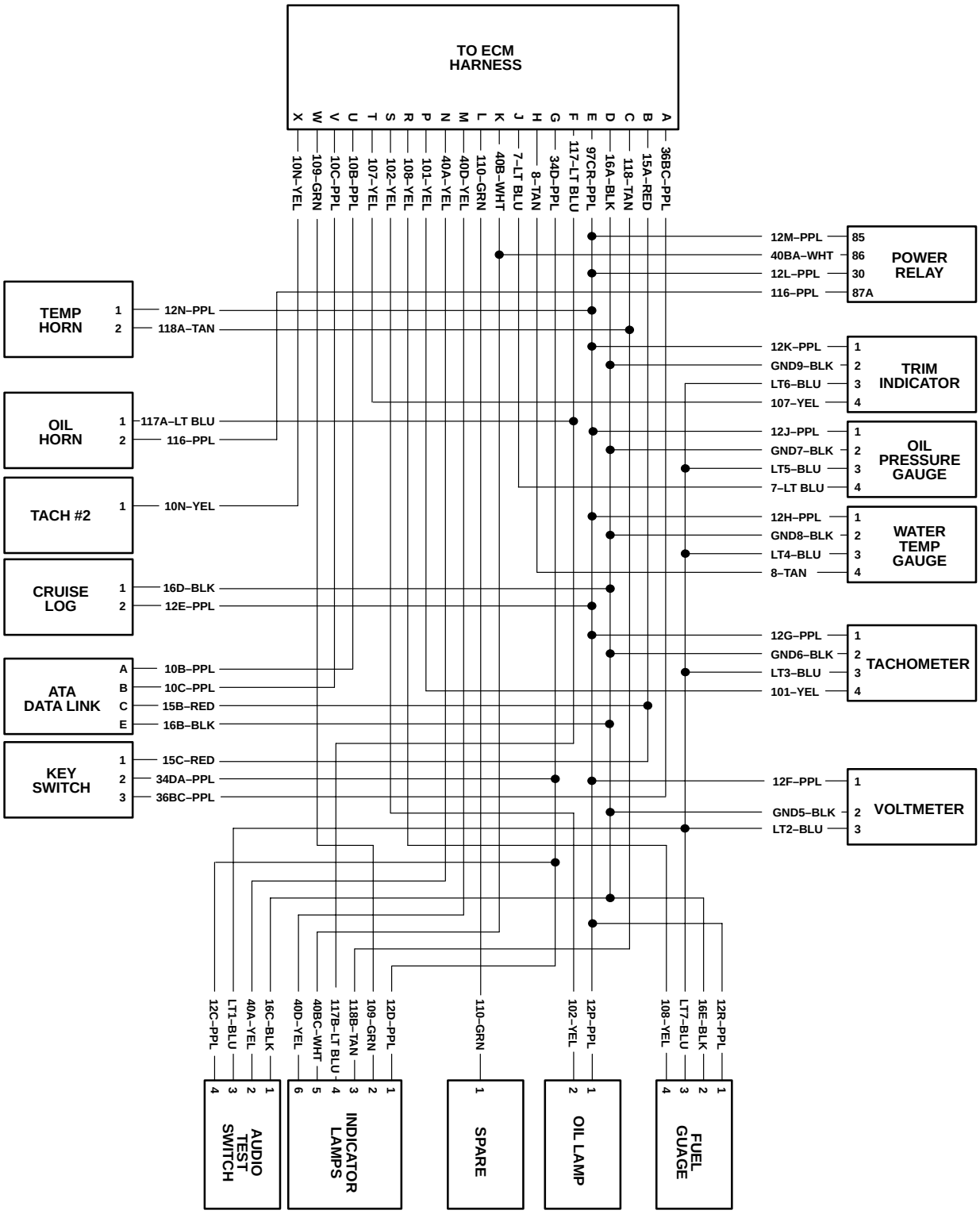
76101

Engine Harness



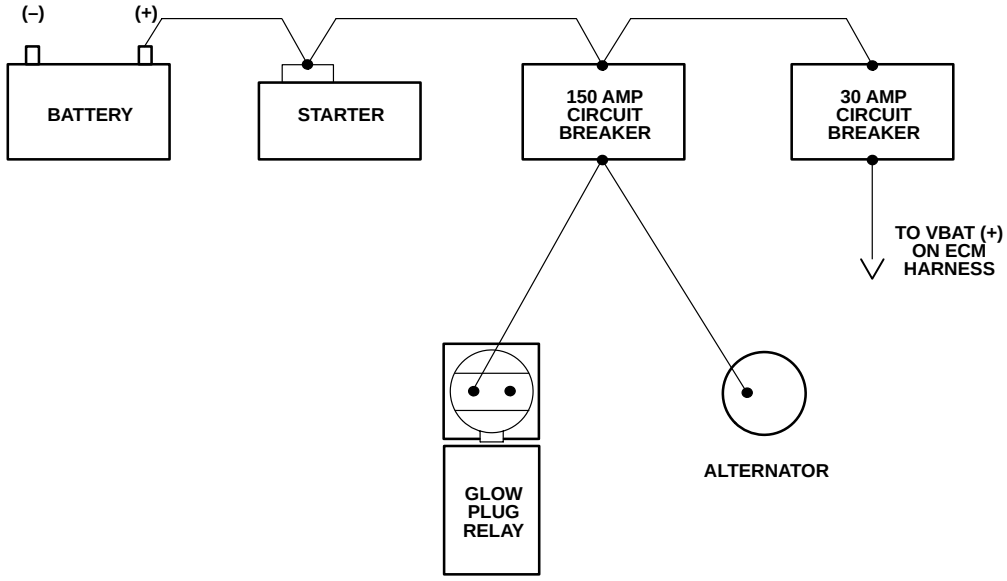
76188

Instrument Harness



76189

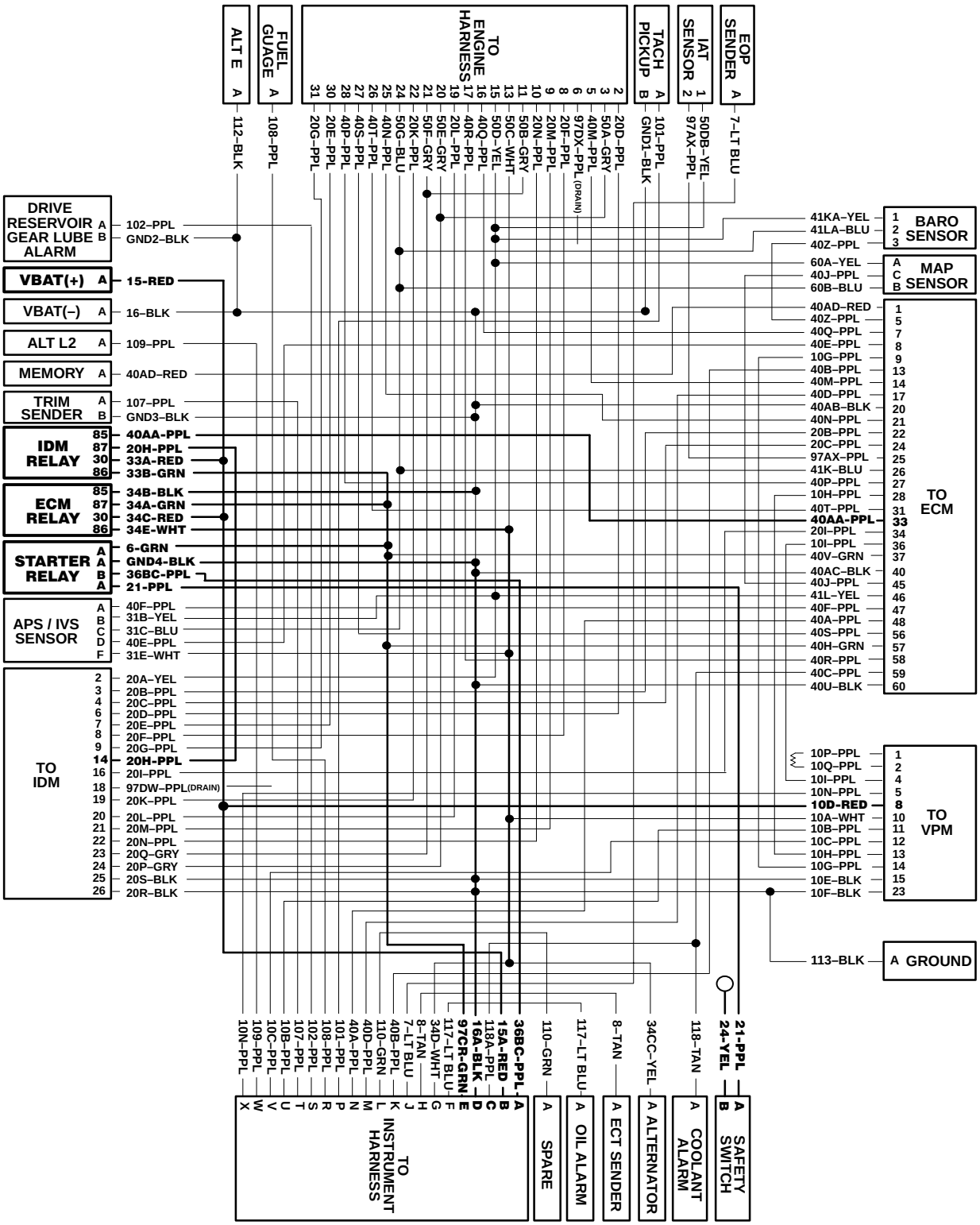
Circuit Breakers and Power Circuits



76190

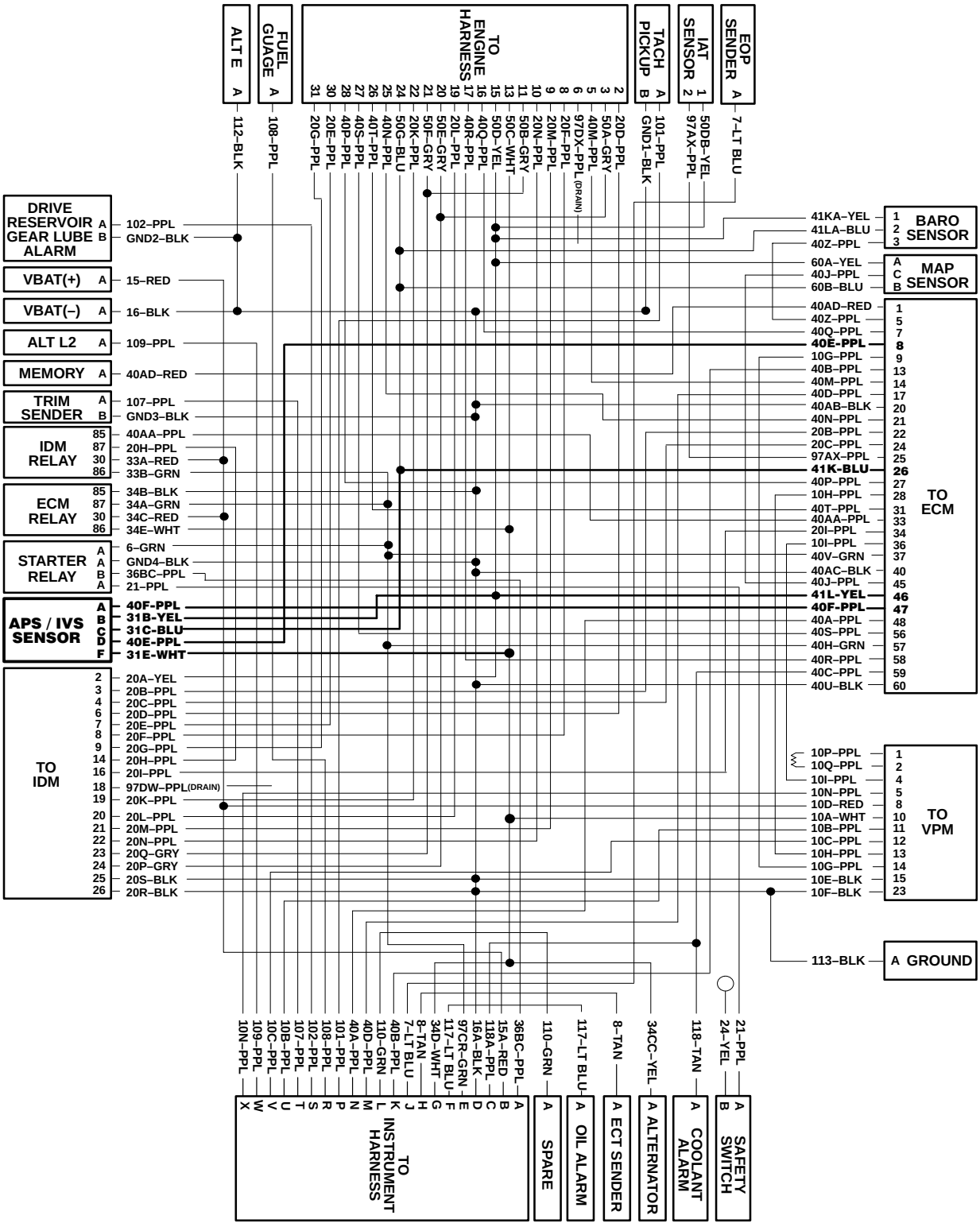
Circuit Diagrams

Relay and Power Circuits



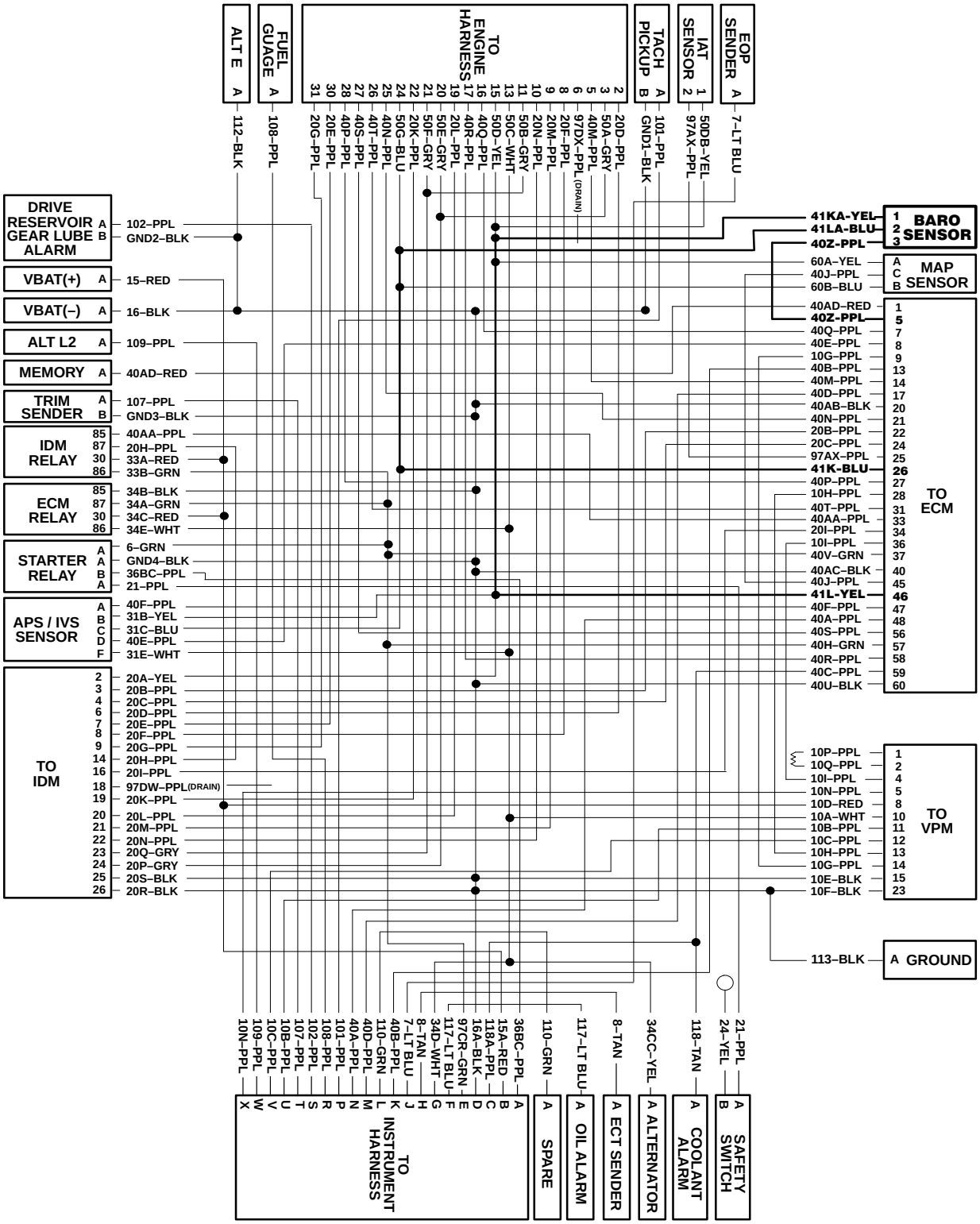
76200

APS/IVS Circuits



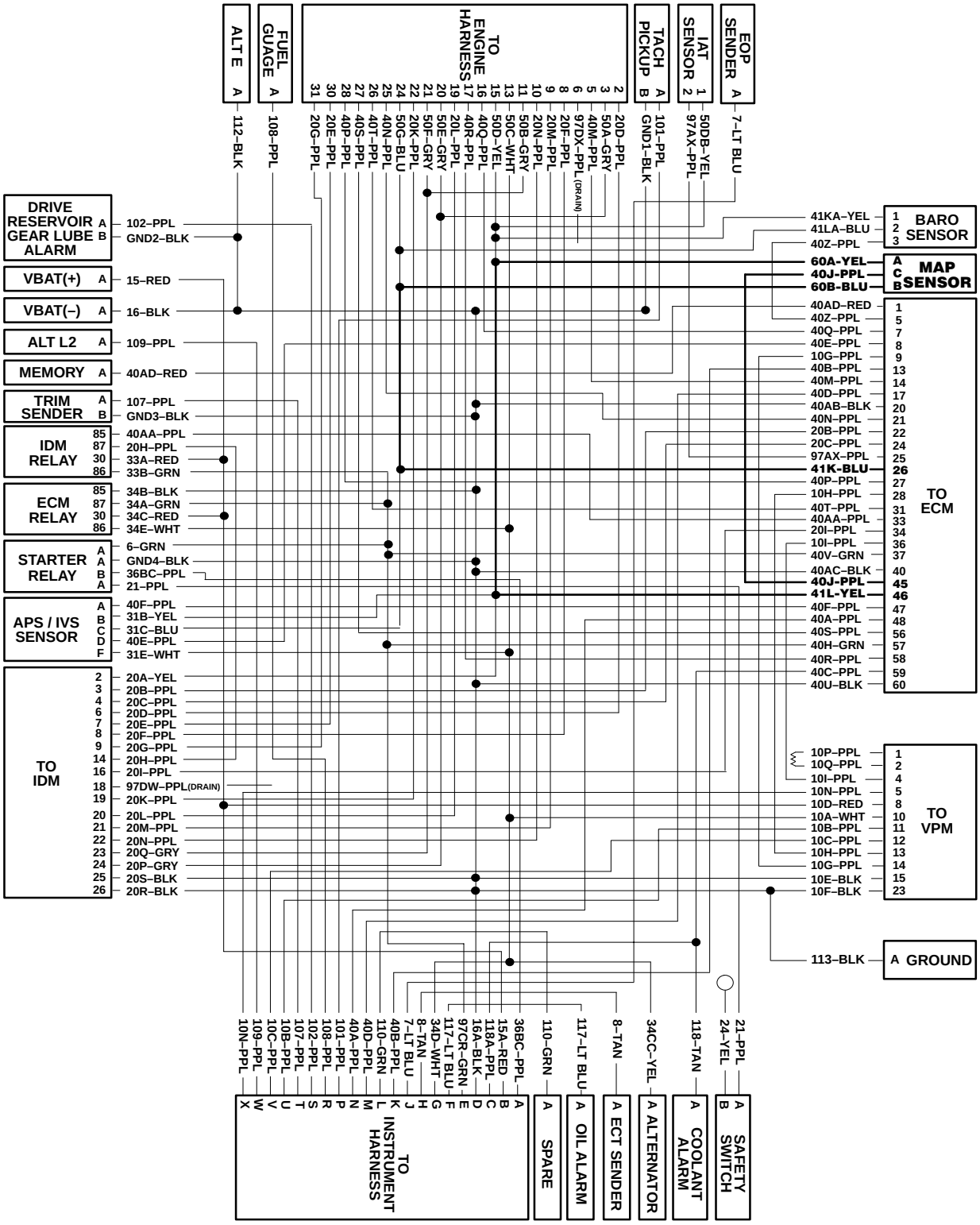
76191

BARO Circuit



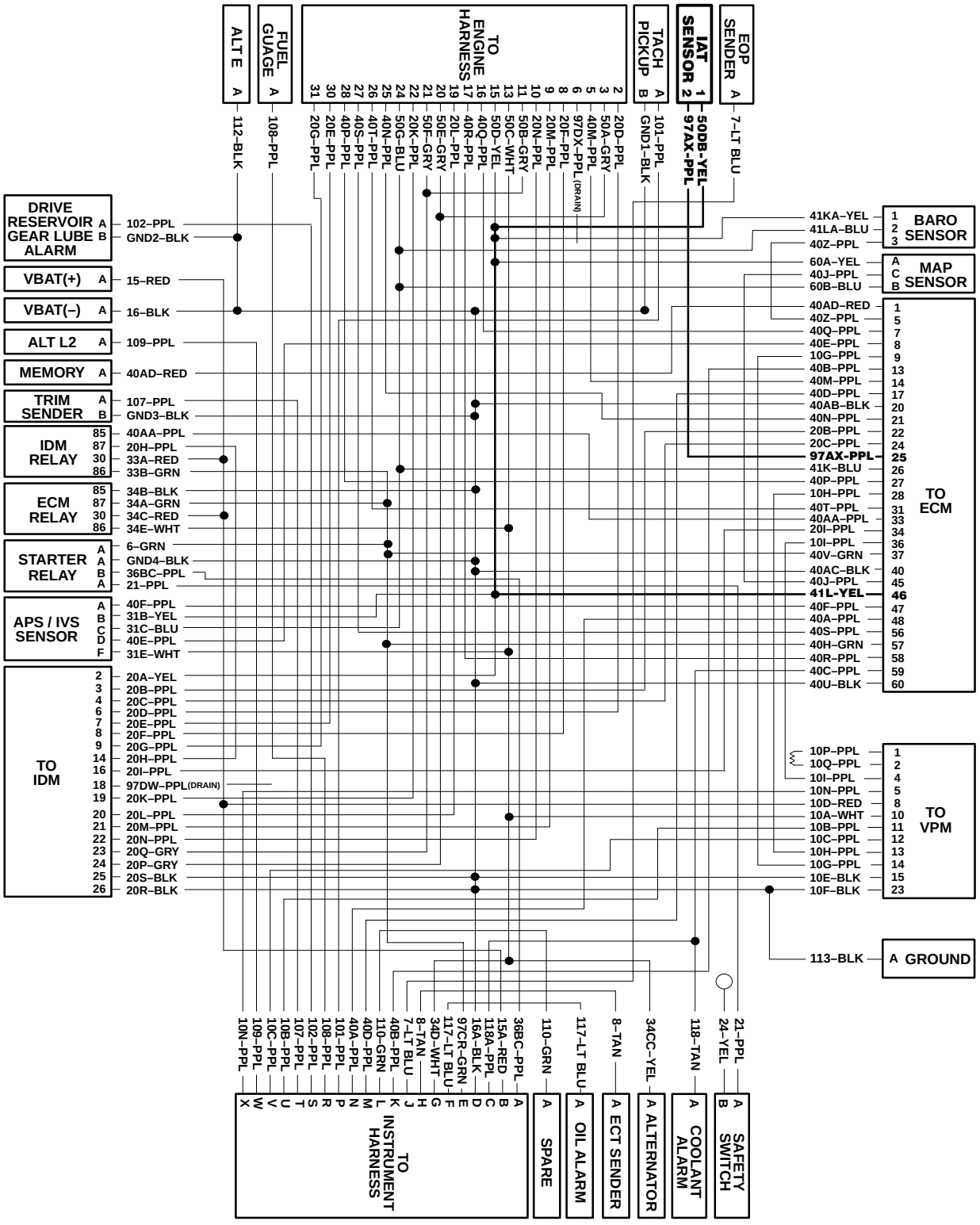
76192

MAP Circuit



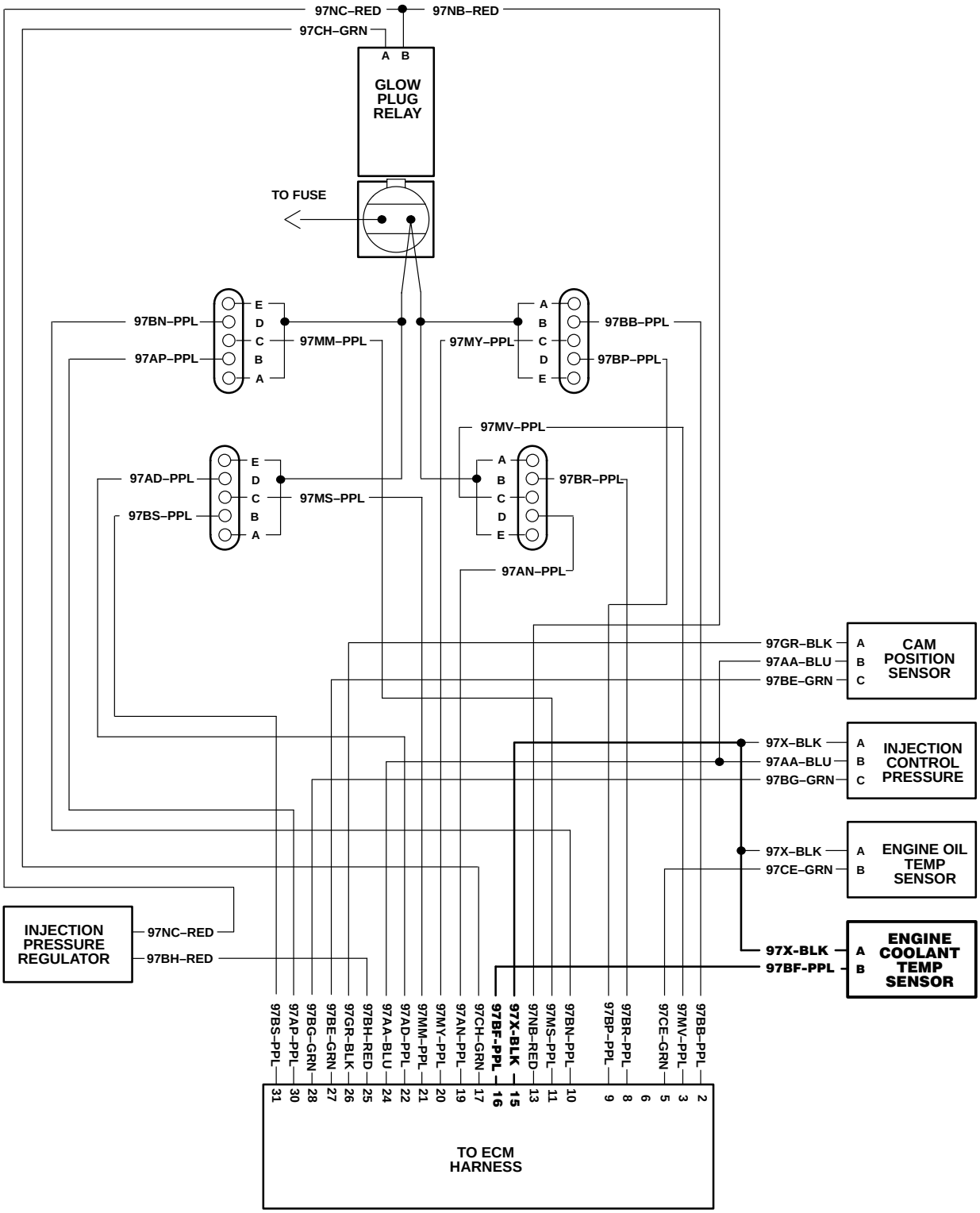
76199

IAT Circuit


ALT E A
FUEL GUAGE A
TO ENGINE HARNESS
TACH PICKUP A B
IAT SENSOR 1 2
EOP SENDER A
112–BLK
108–PPL
20G–PPL 20E–PPL 40P–PPL 40S–PPL 40T–PPL 40N–PPL 50G–BLU 20K–PPL 50F–GRY 50E–GRY 20L–PPL 40R–PPL 40Q–PPL 50D–YEL 50C–WHT 50B–GRY 20N–PPL 20M–PPL 20F–PPL 97DX–PPL (DRAIN) 40M–PPL 50A–GRY 20D–PPL
101–PPL GND1–BLK
50DB–YEL
97AX–PPL
7–LT BLU
DRIVE RESERVOIR GEAR LUBE ALARM A B 102–PPL GND2–BLK
VBAT(+) A 15–RED
VBAT(–) A 16–BLK
ALT L2 A 109–PPL
MEMORY A 40AD–RED
TRIM SENDER A B 107–PPL GND3–BLK
IDM RELAY 85 87 30 86 40AA–PPL 20H–PPL 33A–RED 33B–GRN
ECM RELAY 85 87 30 86 34B–BLK 34A–GRN 34C–RED 34E–WHT
STARTER RELAY A A B A 6–GRN GND4–BLK 36BC–PPL 21–PPL
APS / IVS SENSOR A B C D F 40F–PPL 31B–YEL 31C–BLU 40E–PPL 31E–WHT
TO IDM 2 3 4 6 7 8 9 14 16 18 19 20 21 22 23 24 25 26 20A–YEL 20B–PPL 20C–PPL 20D–PPL 20E–PPL 20F–PPL 20G–PPL 20H–PPL 20I–PPL 97DW–PPL (DRAIN) 20K–PPL 20L–PPL 20M–PPL 20N–PPL 20Q–GRY 20P–GRY 20S–BLK 20R–BLK
41KA–YEL 41LA–BLU 40Z–PPL
BARO SENSOR 1 2 3
60A–YEL 40J–PPL 60B–BLU
MAP SENSOR A C B
40AD–RED 40Z–PPL 40Q–PPL 40E–PPL 10G–PPL 40B–PPL 40M–PPL 40D–PPL 40AB–BLK 40N–PPL 20B–PPL 20C–PPL 97AX–PPL 41K–BLU 40P–PPL 10H–PPL 40T–PPL 40AA–PPL 20I–PPL 10I–PPL 40V–GRN 40AC–BLK 40J–PPL 41L–YEL 40F–PPL 40A–PPL 40S–PPL 40H–GRN 40R–PPL 40C–PPL 40U–BLK
TO ECM 1 5 7 8 9 13 14 17 20 21 22 24 25 26 27 28 31 33 34 36 37 40 45 46 47 48 56 57 58 59 60
10P–PPL 10Q–PPL 10I–PPL 10N–PPL 10D–RED 10A–WHT 10B–PPL 10C–PPL 10H–PPL 10G–PPL 10E–BLK 10F–BLK
TO VPM 1 2 4 5 8 10 11 12 13 14 15 23
113–BLK
A GROUND
10N–PPL 10P–PPL 10C–PPL 10B–PPL 10U–PPL 10T–PPL 10S–PPL 10R–PPL 10P–PPL 10N–PPL 40A–PPL 40D–PPL 110–GRN 40B–PPL 7–LT BLU 8–TAN 34D–WHT 117–LT BLU 97CR–GRN 16A–BLK 118A–PPL 15A–RED 36BC–PPL
TO INSTRUMENT HARNESS X W V U T S R P N M L K J H G F E D C B A
110–GRN
A SPARE
117–LT BLU
A OIL ALARM
8–TAN
A ECT SENDER
34CC–YEL
A ALTERNATOR
118–TAN
A COOLANT ALARM
24–YEL 21–PPL
A B SAFETY SWITCH

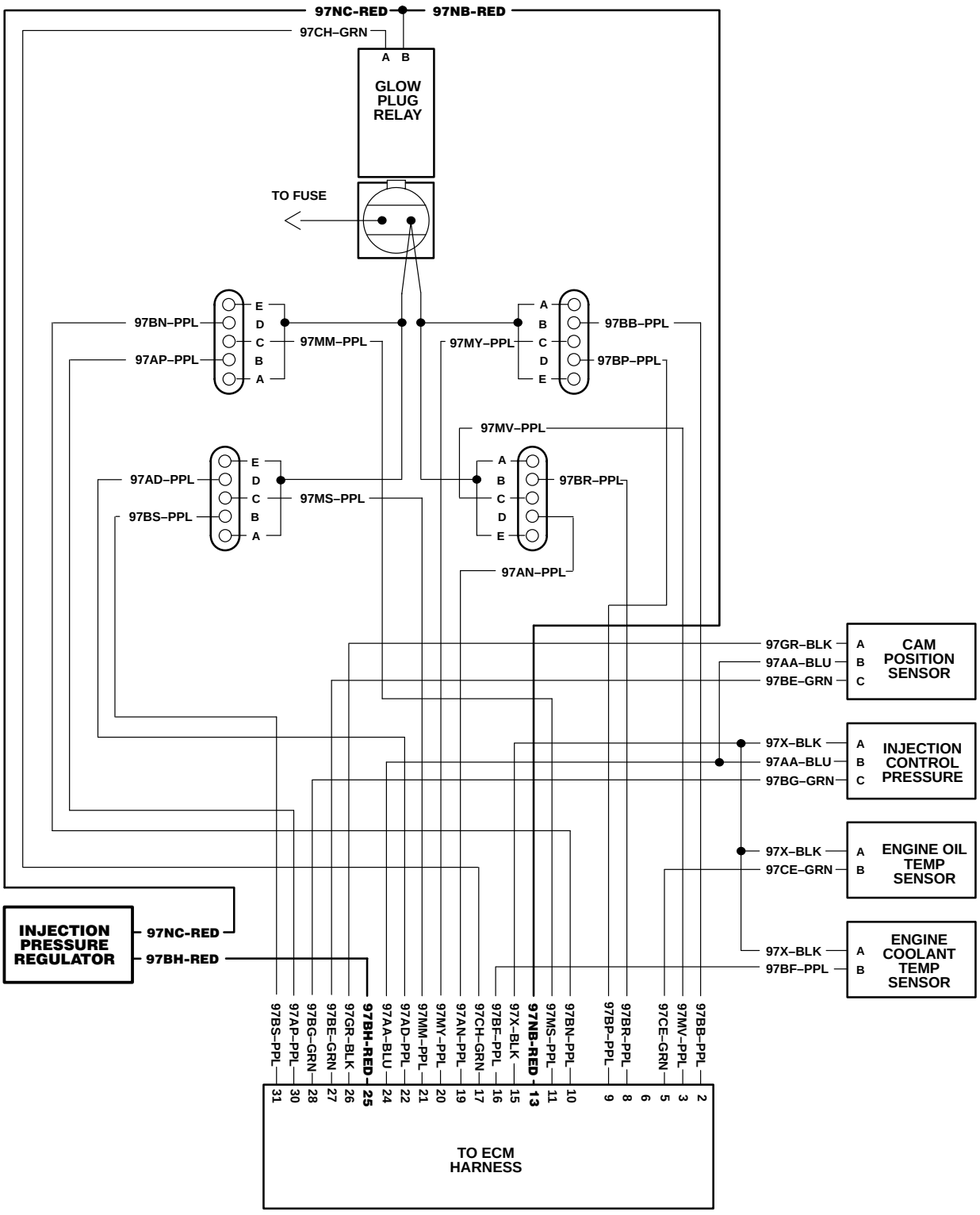
76196

ECT Circuit



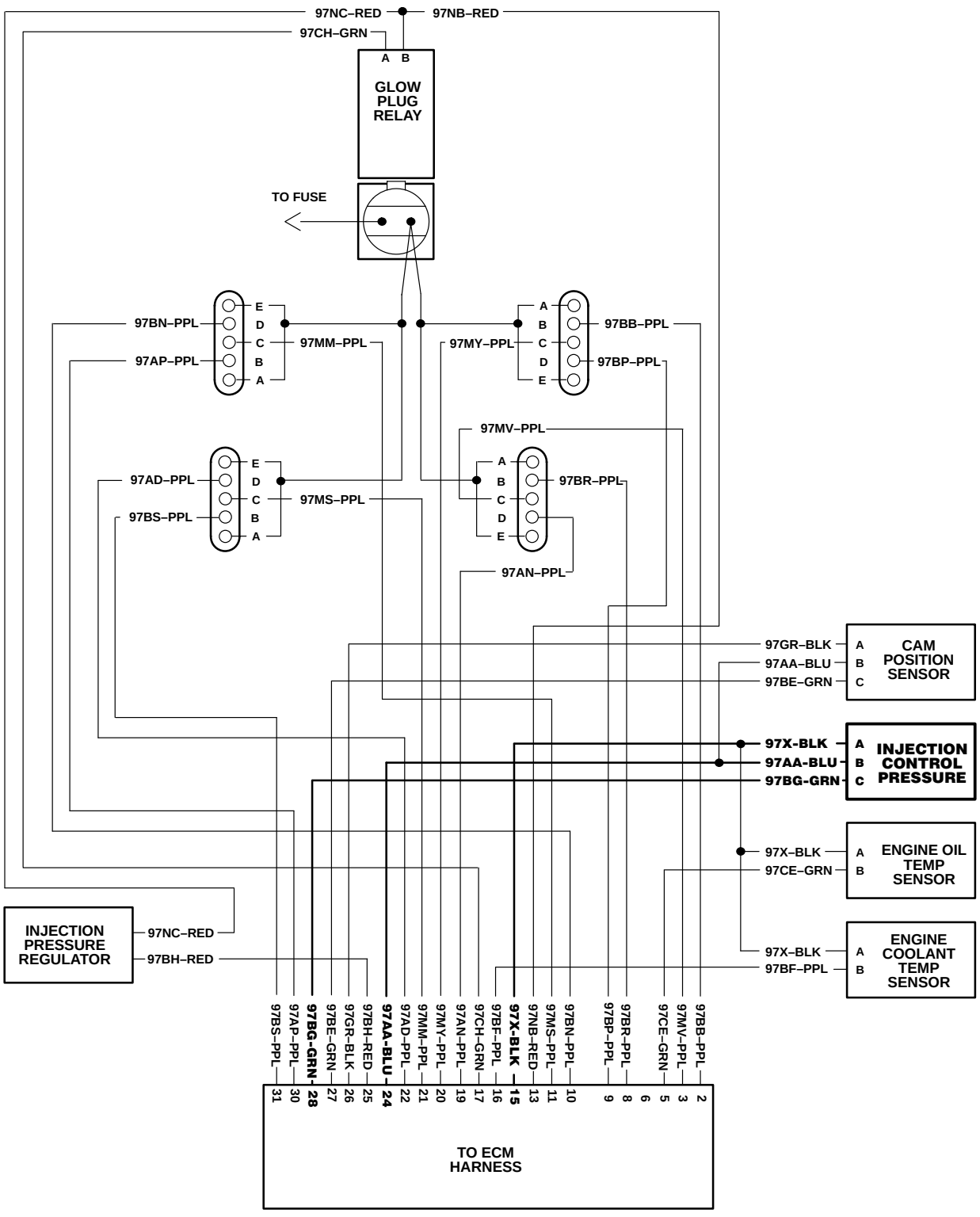
76193

IPR Circuit



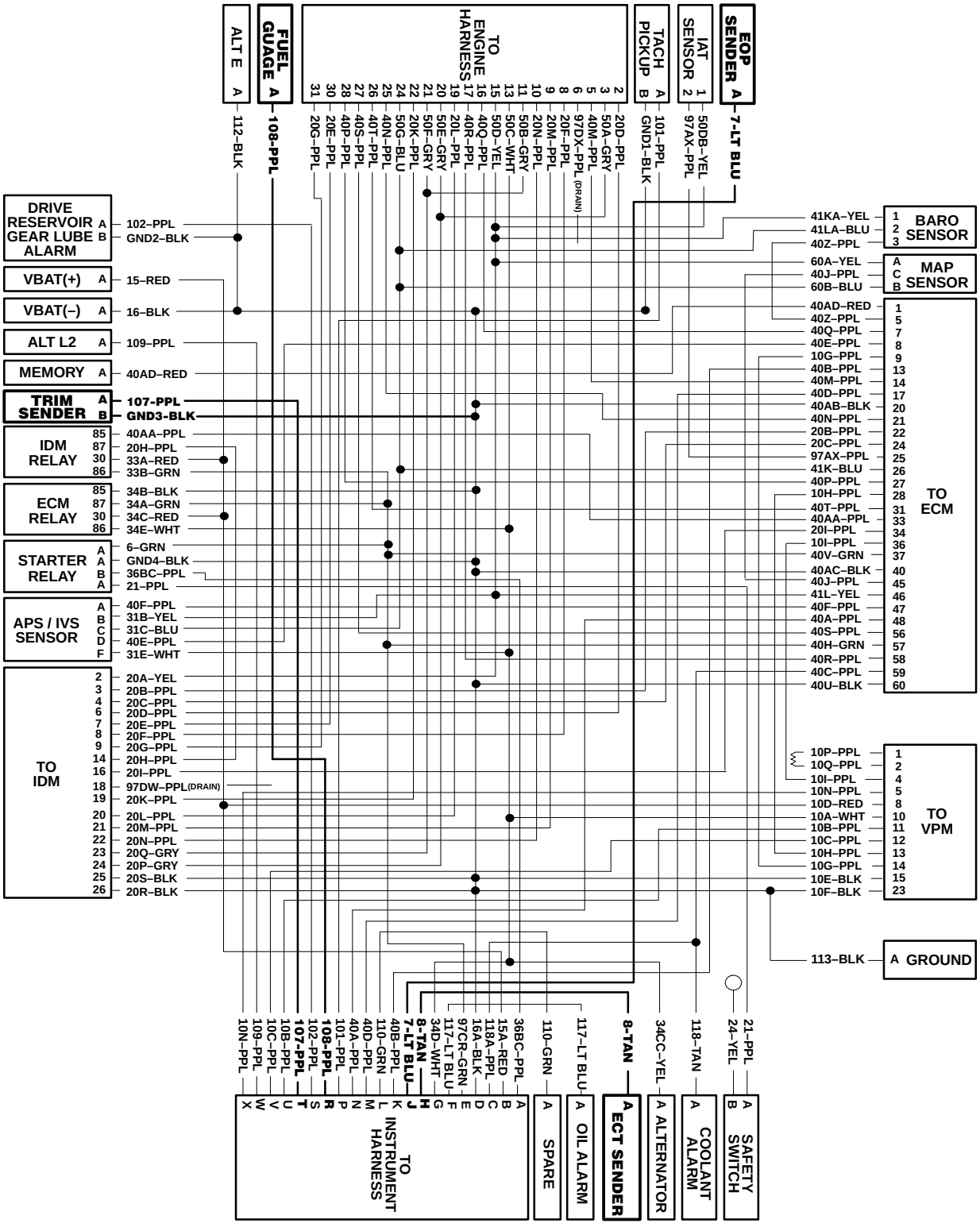
76194

ICP Circuit



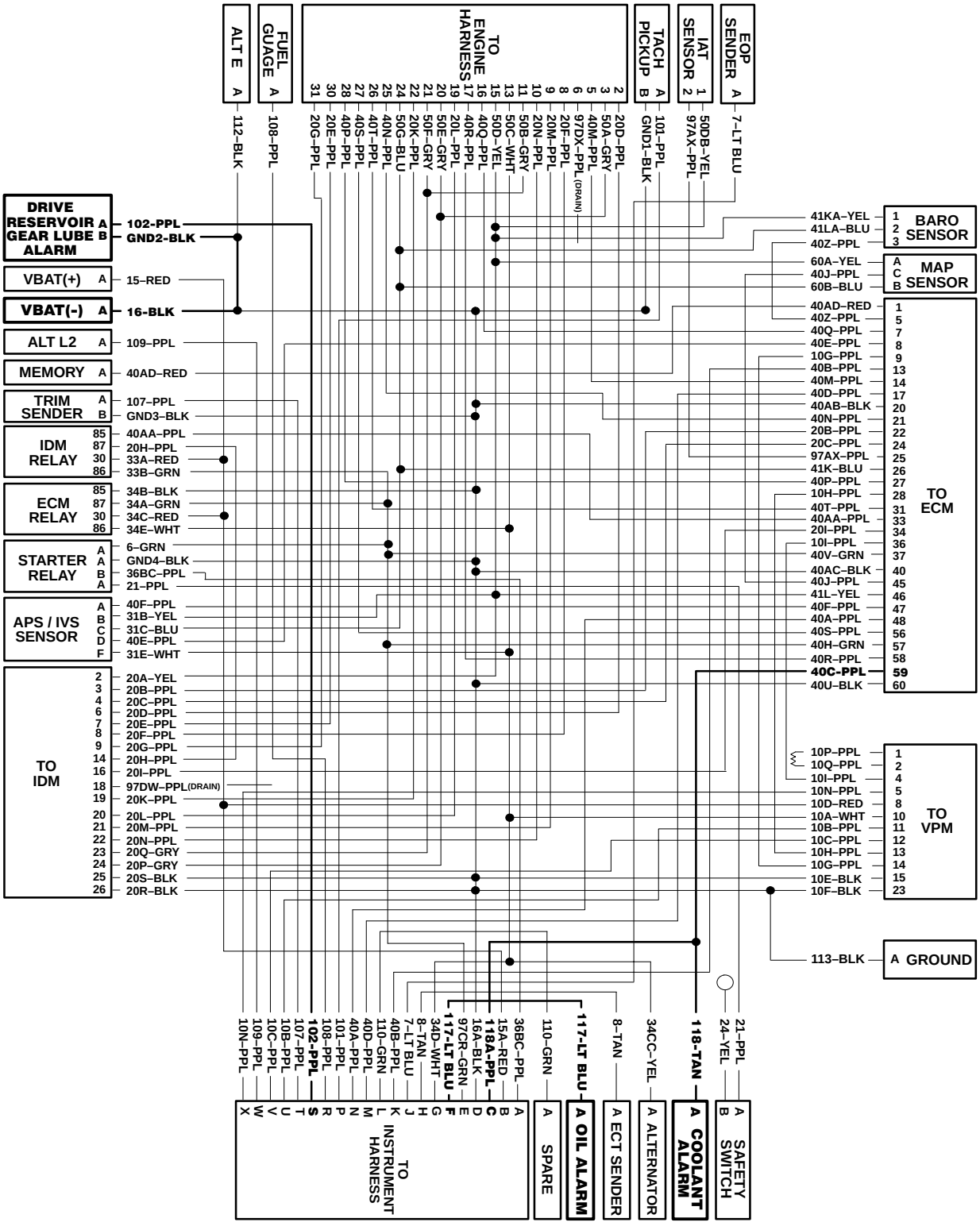
76195

Gauge Circuits



76197

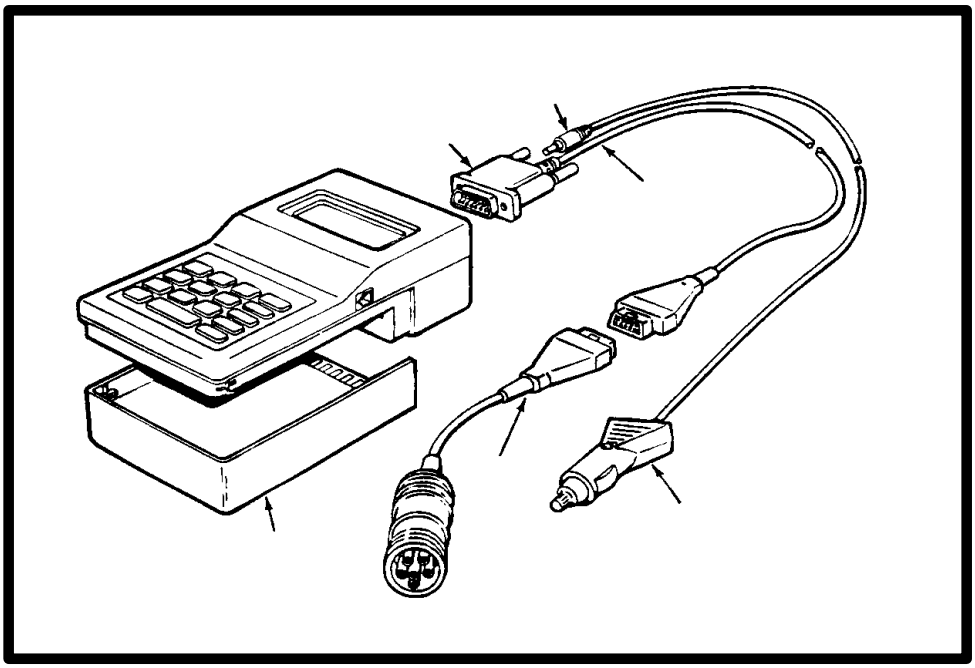
Alarm Circuits



76198

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FUEL SYSTEM



5

D

DIAGNOSTIC TOOL USE

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MerCruiser Special Tools List

DESCRIPTION	Supplier P/N	MP P/N
Cylinder head lifting bracket	ZTSE4297	
Compression gauge	ZTSE2482A	
Compression gauge adapter	ZTSE4292	
Valve spring tester	ZTSE2241	
Valve spring compressor	ZTSE4298	
Injector sleeve remover	ZTSE4302	
Injector/front seal removal	ZTSE4300	
Injector sleeve installer	ZTSE4303	
Injector tip brush	ZTSE4301	
Injector sleeve brushes	ZTSE4304	
Injector sleeve seat brush	ZTSE4305	
Cylinder head coolant plate	ZTSE4308	
Cylinder head bolt bottom tap	ZTSE43862	
Injector holder rack and caps	ZTSE4299	
Cleaning brush set	ZTSE4320	
Injector remover	ZTSE4354	91-854264
Injector installer	ZTSE4353	91-854265
Damper wear ring remover	ZTSE4314	
Damper wear ring installer	ZTSE4315	
Damper and front seal installer	ZTSE-4310	
Hydraulic valve lifter tester	ZTSE-1893	
Flex hone	ZTSE4349	
“Plasti-gage”	D81L6002B	
Crankcase cup plug installer	ZTSE4309	
Rod guide caps	ZTSE4311	
Camshaft bushing tools	ZTSE2393C	
Keystone pin gauges	ZTSE30201	
Front crankshaft oil seal installer	ZTSE4310	
Crankshaft wear ring remover	ZTSE4317	
Crankshaft wear ring installer	ZTSE4318	
Engine harness repair kit	ZTSE4291	
High pressure oil system cap set	ZTSE4295	
Fuel system cap set	ZTSE4294	
Fluke 88 digital multimeter		
Injection control pressure high pressure leak test tool	EG-132	91-854266
Glow plug/injector “T” harness	ZTSE-4345	91-854267
Pressure test kit box	ZTSE-2239	91-854268
Injection control pressure(ICP) “T” harness	ZTSE-4347	91-854269
Crankcase orifice restrictor and adapter	ZTSE-4146-A ZTSE-4284	91-854270 91-854271
Exhaust back pressure sensor “T” harness	ZTSE-4347	
Break out box	ZTSE-4346	91-854272
Rinda diagnostic tool	94050M	
Electronic diagnostic tool kit includes : • Prolink 9000 • Cartridge • Adapter Cable • Data Cable	 • ZTSE-43661 • ZTSE-43667 • ZTSE-436633A • ZTSE-501003	91-854273

Tools without MP P/N Can be Ordered to:

PROLINK: OTC Division, SPX Corp
655 Eisenhower Drive
Owatonna, Minnesota 55060
Ph: 507-455-7244
Fax: 800-283-8665

RINDA: Rinda Technologies Inc.
4563 Elston Avenue
Chicago, Illinois 60630
Ph: 312-736-6633
Fax: 312-736-2950

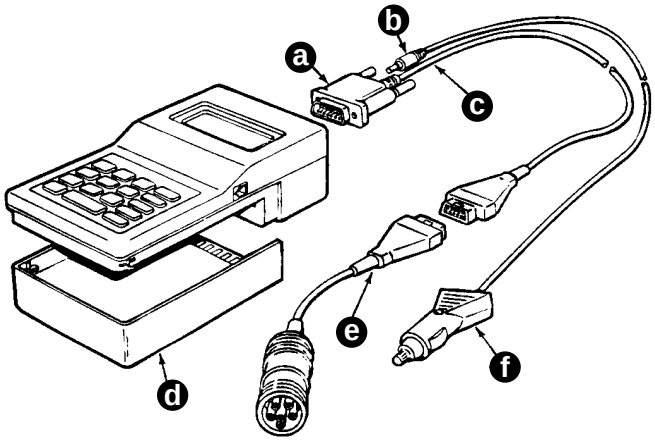
MCA: Marine Corporation Of America
980 Hurricane Road
Franklin, IN 46131
Ph: 317-738-9408
Fax: 317-738-4330

MPE: Marine Power Europe, Inc.
Parc industriel de Petit-Rechain
4800 Verviers - Belgium
Ph: 32(87)32.32.11
Fax: 32(87)31.19.65

Diagnostic Tools

PRO-LINK 9000

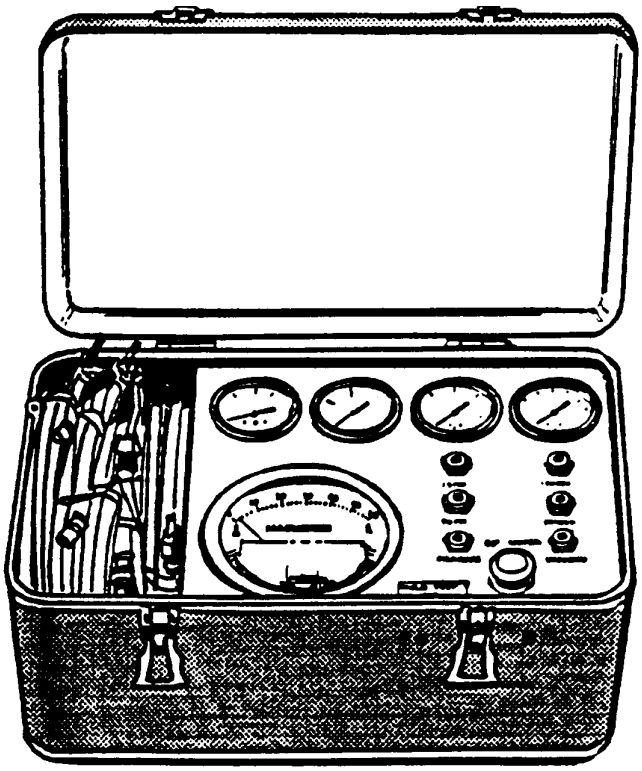
- Data Readout Window
- Soft Touch Keypad
- Data and Power Cable Connector
- RS232 Serial Data Port
- Push button



Pro-Link 9000 (ZTSE-43661)

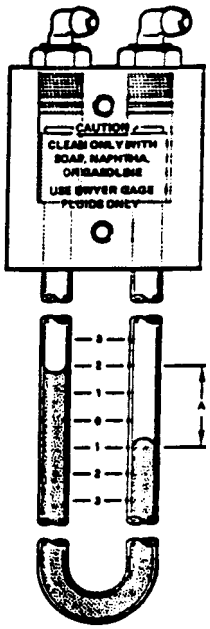
a - 15 Pin Vehicle Cable
b - Power Cable
c - Data Cable
d - Data Cartridge (Specific cartridge for each application)
e - Adapter
f - Power Cable (Not needed for some applications)

PRESSURE TEST KIT MODEL D-200



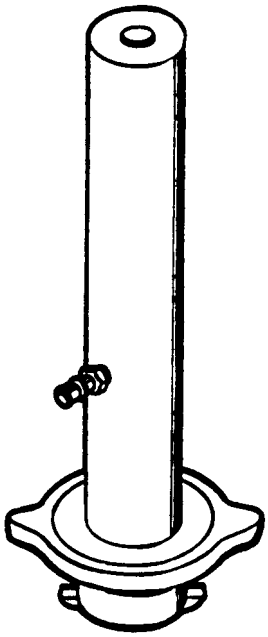
Pressure Test Kit Model D-200 (ZTSE-2239)

SLACK TUBE MANOMETER



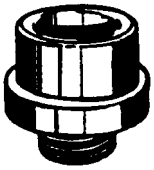
Slack Tube Manometer (Dwyer No. 1211-48)

ORIFICED RESTRICTOR TOOL



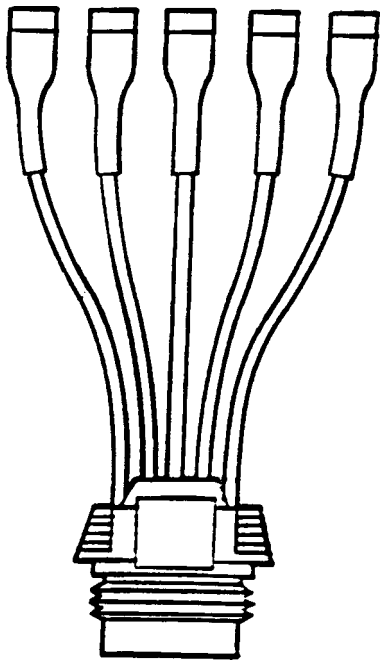
Orificed Restrictor Tool (ZTSE-4146A)

CRANKCASE RESTRICTOR ADAPTER



Crankcase Restrictor Adapter (ZTSE-4284)

GLOW PLUG / INJECTOR BREAKOUT



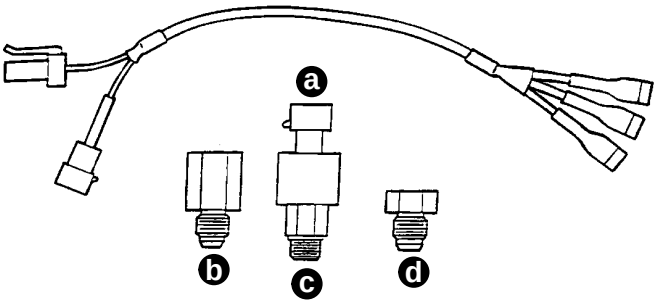
Glow Plug / Injector Breakout (ZTSE-4345)

ICP / EBP BREAKOUT “T”



ICP / EBP Breakout “T” (ZTSE-4347)

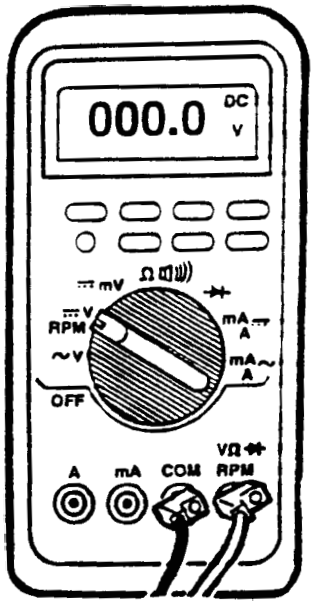
INJECTION CONTROL PRESSURE HIGH PRESSURE LEAK TEST TOOLS



Injection Control Pressure High Pressure Leak Test Tools

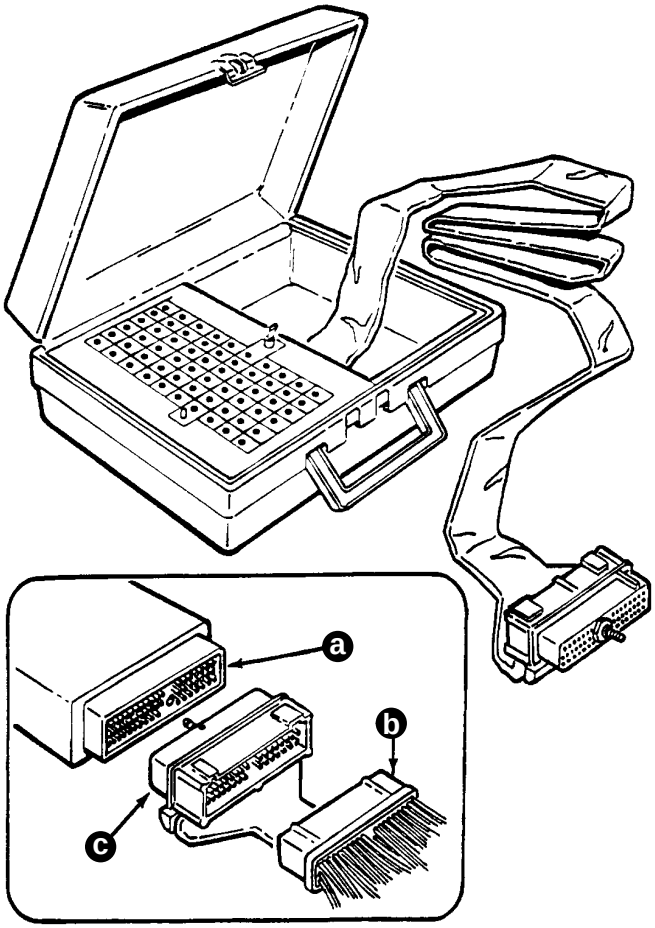
a - ICP Breakout Tee
b - Adapter
c - ICP Sensor
d - Plug

FLUKE 88 DIGITAL MULTIMETER



Fluke 88 Digital Multimeter

Breakout Box



Breakout Box (ZTSE-4346)

a - Engine Microprocessor (ECM)
b - Engine Harness
c - Breakout Box Connector

Beyers Model 200 Pressure Test Kit (ZTSE-2239)

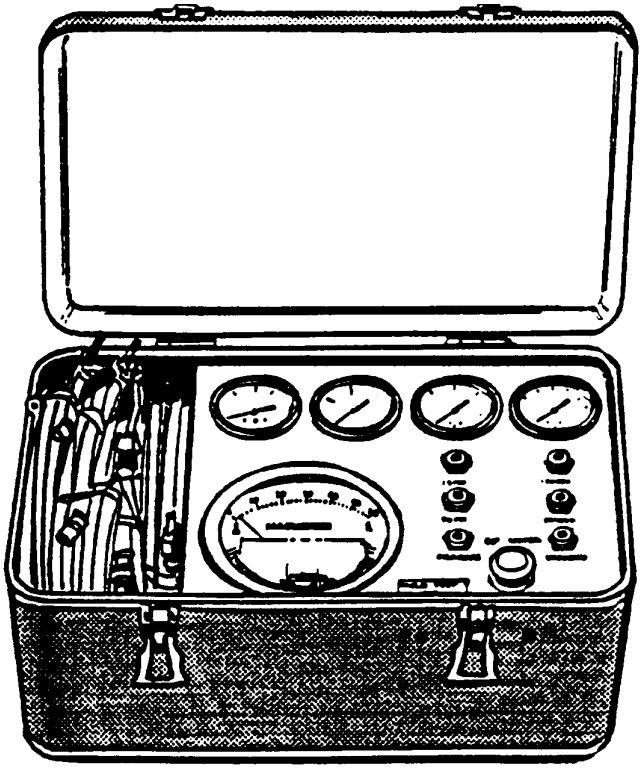
DESCRIPTION

The Pressure Test Kit can be used to measure intake manifold (Boost) pressure, fuel pressure, air cleaner restriction, fuel restriction, exhaust back pressure and crankcase pressure. It may also be used to test the accuracy of the gauges within the kit.

The 0-30 psi gauge may be used to measure fuel pressure or intake manifold (Boost) pressure.

The 0-30 in. Hg. vacuum gauge (0-14.7 psi) is used to measure fuel system inlet restriction.

The 0-60 inches of water (magnehelic) gauge (0 2.16 psi) may be used to measure air cleaner restriction or crankcase pressure.



Pressure Test Kit Model D-200 (ZTSE-2239)

⚠CAUTION

The quick disconnects have shut-off valves in the panel connectors not in the plug. DO NOT connect or disconnect lines while under pressure.

NOTE: *When using the magnehelic gauge, be sure to plug the test line into the proper ("Pressure" or "Vacuum") port. Use the "Pressure" port to read exhaust back pressure and crankcase pressure. Use "Vacuum" port to read air cleaner restriction. In both cases, THE OPPOSITE CONNECTOR MUST BE VENTED TO THE ATMOSPHERE BY INSTALLING A QUICK CONNECTIVE PLUG IN THE PORT.*

The 0-160 psi gauge may be used to check fuel pressure.

The 0-300 psi gauge is not normally used for any engine diagnostic check.

MAINTENANCE AND GAUGE ACCURACY TEST

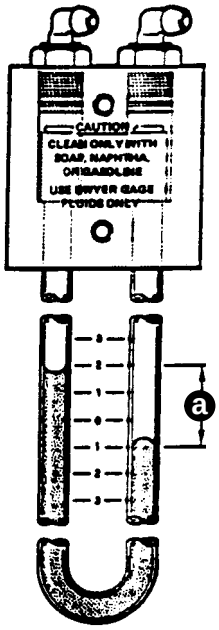
1. Remove cover of pressure test kit and inspect for damage to gauges such as broken cover glass, bent gauge needles, and for missing pressure connectors and nylon tubing. Replace damaged or missing parts so that the kit will operate when needed.
2. Remove the screws holding the gauge panel to carrying case and lift the panel from the carrying case. If any liquids are found in the tubing behind the panel, loosen the connections and blow out the liquids. Tighten all connectors as required and reassemble the gauge panel.
3. The hand operated pump is directly connected to 0-30 psi gauge when the kit is received. If a gauge accuracy test is desired, proceed as described under CALIBRATING THE PRESSURE KIT using the Dwyer Slack Tube Manometer, in this section.

OPERATING INSTRUCTIONS

Connect tubes between the test ports on the panel and the test points shown on the (REAR SIDE) of HARD START NO START AND PERFORMANCE DIAGNOSTIC FORM EGED-130.

Dwyer Slack Tube Manometer

DESCRIPTION



Slack Tube Manometer (Dwyer No. 1211-48)

a - Dimension Indicates Total Fluid Column

The manometer is a “U” shaped tube with a scale mounted between the legs of the “U”. Where the portability of the Model 200 Pressure Test Kit is not required, this manometer can be used to measure either low pressure or vacuum and may be filled with water.

Order from: Dwyer Instruments, Inc.
P0. Box 373
Michigan City, Indiana 46360
Phone: (219) 872-9141

FILLING

The manometer may be filled with water, when checking very low pressures.

When filling with water, use only good drinking water without additives except for some colored water vegetable dye which enables the tester to read the scale easier. With both legs of the manometer open to the atmosphere, fill the tube until the top of the fluid column is near the zero mark on the scale. Shake the tube to eliminate any air bubbles.

IMPORTANT: Never use an antifreeze solution, soda pop, tonic, etc. the increase in density causes false readings.

INSTALLING AND READING

1. Support the manometer in a vertical position. Be sure the fluid is at the zero mark on the scale.
2. Connect one leg of the manometer to the source of the pressure or vacuum. Be sure the other leg is open to atmosphere.
3. Start the engine and when the engine is in the proper operating condition as specified, observe the manometer.
4. After about two minutes, record the average position the fluid level is above and below the zero mark. Add the two figures together. The sum of the two is the total column of fluid.

NOTE: *At times both columns of the manometer will not travel the same distance. This is of no concern to the tester as long as the leg not connected to the pressure or vacuum source is open to the atmosphere.*

CLEANING

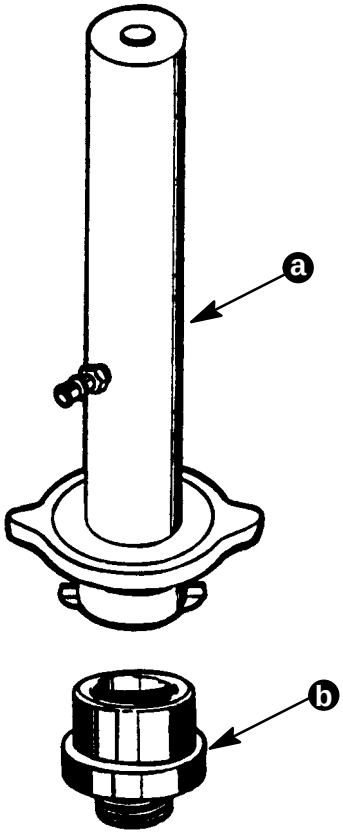
1. Wash the tube thoroughly with a little pure soap and water. Avoid liquid soaps and solvents.

Orificed Restrictor Tool (ZTSE-4146A) and Adapter (ZTSE-4284)

DESCRIPTION

This Orificed Restrictor tool (ZTSE-4146A) in conjunction with the Restrictor Adapter (ZTSE-4284) are used to measure combustion gas flow out of the engine. The Orificed Restrictor contains an integral oil fill cap which provides nearly effortless set-up when performing a crankcase pressure test on the Diesel Engine. The Model D-200 Pressure Test Kit and a plastic cap are also required to perform the crankcase pressure test.

IMPORTANT: Pressure readings obtained with this restrictor must not be used as the main source of engine condition. Oil consumption trend data must also be used if the pressure readings are beyond the specified limits. Neither changes in oil consumption trends nor crankcase diagnostic pressure trends can establish a specific component problem but are only indicators that some problem exists.



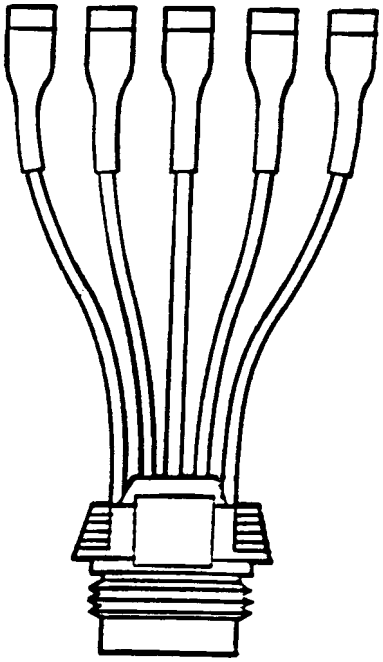
Crankcase Pressure Diagnostic Tools

a - Orificed Restrictor Tool (ZTSE-4146A)
b - Crankcase Restrictor Adapter (ZTSE-4284)

Glow Plug/Injector Breakout (ZTSE-4345)

DESCRIPTION

The Glow Plug/Injector breakout tool (ZTSE-4345) is used to check injector solenoid continuity and glow plug resistance to ground. Use of this tool is shown in Mechanical Diagnostics Section 1.



Glow Plug/Injector Breakout (ZTSE-4345)

ICP/EBP Breakout “T” (ZTSE-4347)

DESCRIPTION

ICP Injection Control Pressure / Exhaust Back Pressure Sensor Breakout “T” (ZTSE -4347) is used to gain access to Injection Control Pressure and Exhaust Back Pressure signal voltages. The “T” enables the technician to quickly connect a voltmeter to read voltage (pressure) signals at each of the sensors. Use of the “T” to measure Injection Control Pressure is shown in Mechanical Diagnostics Section 1. For use in measuring exhaust back pressure refer to Mechanical Diagnostics Section 2.

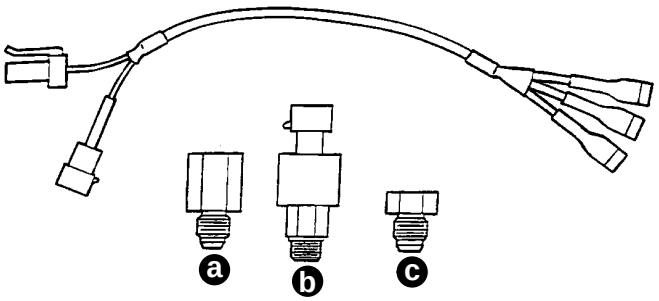


ICP/EBP Breakout “T” (ZTSE-4347)

High Pressure Leakage Test Tool/Adapters

DESCRIPTION

The ICP/EBP breakout “T”, adapter, plug and ICP sensor are used to perform High Pressure Leakage Tests on the Injection Control Pressure system. Refer to High Pressure Leakage Tests in Mechanical Diagnostics Section 1 for use of these tools/adapters.



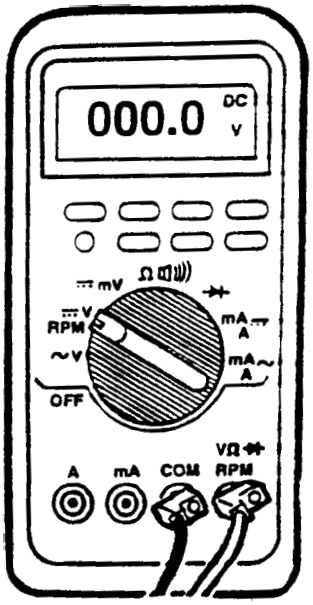
High Pressure Leakage Test Tools

a - Adapter
b - ICP Sensor
c - Plug

Fluke 88 Digital Multimeter

DESCRIPTION

The Fluke 88 multimeter allows the technician to troubleshoot the electrical components (sensors, injector solenoids, relays, wiring harnesses, etc.) associated with the MCM 7.3L D-Tronic. In addition, it measures engine RPM. This feature allows the technician to measure engine cranking RPM when the Electronic Service Tool (EST) is not available or is unable to receive ATA data. This meter has a high input impedance which allows testing of sensors while the engine is running, without loading the circuit which is being tested. This ensures the signal voltage measurement will not be affected by the voltmeter.

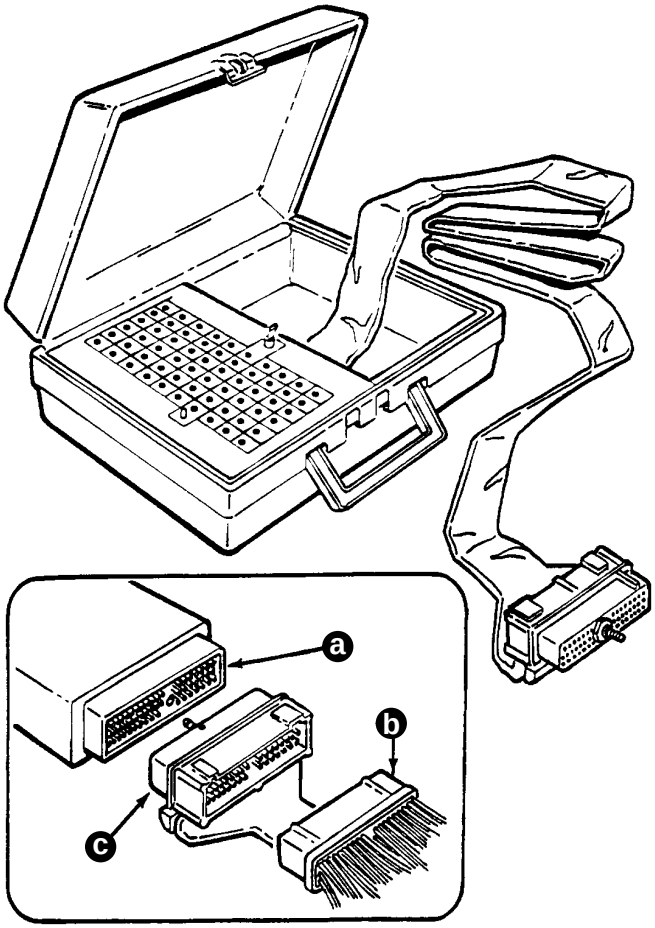


Fluke 88 Digital Multimeter

Breakout Box (ZTSE-4346)

Breakout Box (ZTSE-4346) was designed to allow testing of the electrical system with the ECM hooked up and in the system. This will allow ECM input and output measurement with the components operating.

It should be noted that the Breakout Box should be used for measurement only, and not to activate or control circuits. High current levels passing through the breakout box will burn out internal circuitry.



Breakout Box (ZTSE-4346)

a - Engine Microprocessor (ECM)
b - Engine Harness
c - Breakout Box Connector

BREAKOUT BOX INSTALLATION

1. Remove the weather cover at the engine cowl located on the upper driver's side of vehicle.
2. Remove the 60 way connector from the ECM. Attach the adapter of the breakout box to the ECM and secure the bolt in the center of the adapter to the ECM.
3. Reattach the 60 way connector to the adapter and secure the bolt in the center of the plug to the adapter.

Readings can now be taken at the test connections in the breakout box. The numbers at the test connections correspond to the ECM terminal numbers.

DESCRIPTION

Fault codes can be detected and stored in two components. The lDM (Injector Driver Module), the ECM (Electronic Control Module).

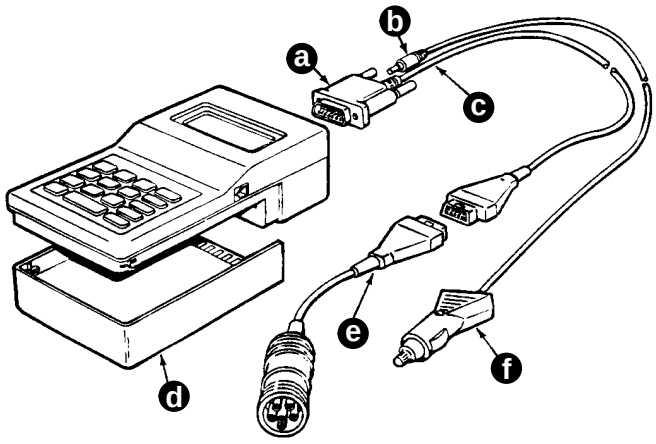
The EST (Electronic Service Tool) is used to access stored fault codes by plugging it into the American Trucking Association (ATA) data link connector.

DIAGNOSTIC CODE RETRIEVAL

Turn all accessories and the ignition off. Connect the EST tool to the (ATA) diagnostic connector.

The screen of the reader should light up as soon as the tool is plugged in.

- Data Readout Window
- Soft Touch Keypad
- Data and Power Cable Connector
- RS232 Serial Data Port
- Push button



Electronic Service Tool Pro-Link 9000 (ZTSE-43661)

a - 15 Pin Vehicle Cable
b - Power Cable
c - Data Cable
d - Data Cartridge (Specific cartridge for each application)
e - Adapter
f - Power Cable (Not needed for some applications)

Turn the ignition key to the "ON" position but do not start the engine. This will allow the EST to receive data from the electronic control components

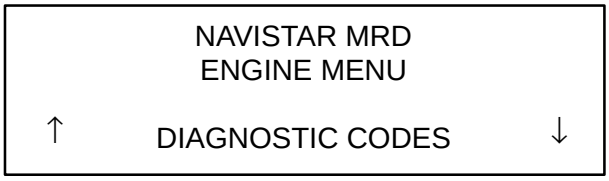
If no data is received press "ENTER" to retry. The information received will be data as to the **current status of the engine.**

To access the fault codes press the “FUNC” key to switch to the main menu.



From the main menu select “ENGINE” by pressing the “←” key. This will cause the brackets to be placed around the “ENGINE” selection. Then press “ENTER”.

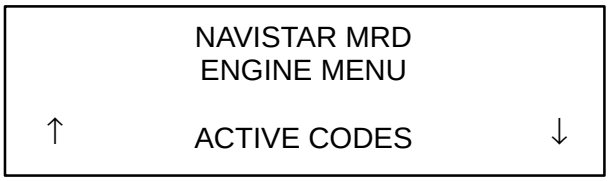
From the next menu, select “DIAGNOSTIC CODES”. The selection will have the “↑↓” symbol on the screen, which means there are other selections available. By pressing the “↓” key the other selections will display on the screen. The first screen that will appear will be “DIAGNOSTIC CODES”. If another option was selected press “↓” key until “DIAGNOSTIC CODES” appears on the screen. Next press “ENTER”. At this point diagnostic codes can be accessed.



ACTIVE CODES

The first option that will appear is “ACTIVE CODES”. By selecting this option, the fault codes that are currently occurring or that have occurred during the last key on cycle will be displayed. Press “ENTER”. If there are any “Active Codes” the first one will appear on the screen along with a description of the code. If there are any additional codes “Active” the “↑↓” symbol will appear on the screen.

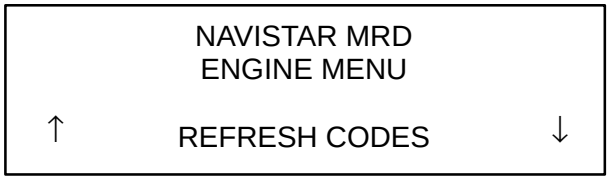
Press “↓” key to access additional codes. If there are not any codes “Active”, “NO ACTIVE CODES” will appear on the screen.



REFRESH CODES

If the fault that caused the “Active Code”, is no longer malfunctioning, it will still be displayed as an “ACTIVE CODE”, until the key is cycled off. To update the active codes in the EST, without turning the key off, press the “FUNC” key to return to the “DIAGNOSTIC CODES” MENU.

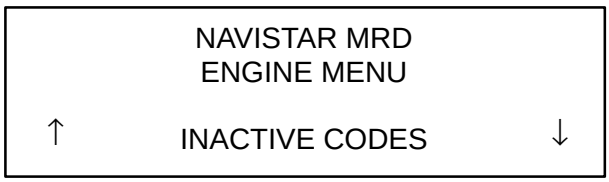
Press the “↓” key repeatedly until the “REFRESH CODES” selection appears on the screen. Press “ENTER” and the codes will update in the EST.



INACTIVE CODES

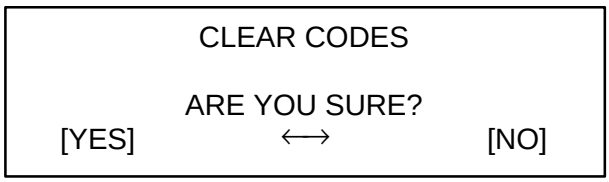
To access “Inactive Codes” press the “FUNC” key. This will access the last prior selection. Then press the “↓” key to select “INACTIVE CODES”. Press the “ENTER” key.

Inactive codes are faults that have occurred in the past, and are now stored in memory. An “Active Code” will become an “Inactive” code if the key is shut off or the malfunction no longer exists (such as an intermittent problem).



CLEAR CODES

To remove the codes from the memory, the EST is equipped with a “CLEAR CODES” option. To access this option, press the “FUNC” key, this will revert back to the “DIAGNOSTIC CODES” menu. Press the “↓” key until “CLEAR CODES” appears on the screen. Press the “ENTER” key and the screen will ask “ARE YOU SURE?” Press the “←” key to select “YES”. Press “ENTER” and the codes will be deleted.



DIAGNOSTIC TESTS

Diagnostic tests are “Self Tests” performed by the electronic components upon demand by the operator. The “Self Tests” check various output circuits to determine if they are functioning properly.

There are two types of self tests.

1. “ENGINE OFF”
2. “ENGINE RUNNING“

“ENGINE OFF” self tests check output circuits electrically for open or short circuits with the **engine not running.**

The “ENGINE RUNNING” test, checks the outputs of engine electronic controls with the **engine running.** The effect on engine operation is measured and compared to an expected level. If **the level of operation is not within** specification, a fault is recorded.

ENGINE OFF TEST

To perform “Engine Off” self tests, turn off all accessories and ignition off. Connect the EST to the ATA connector. Access the “ENGINE OFF TESTS” in the “DIAGNOSTIC TESTS“ section of the EST.

To access this test, press the “FUNC” key. This will allow access to the last prior selection. Or press the “FUNC“ key repeated until the main menu appears on the screen.

```
NAVISTAR MED
SELECT DESIRED MENU

[ENGINE]      ⟷      PRO-LINK
```

Move the brackets to engine selection by pressing the “←” key. Then press “ENTER”.

Next select the “DIAGNOSTIC TESTS” menu by pressing the “↓” key, until “DIAGNOSTIC TESTS” is shown on the screen. Press enter to make this selection.

```
NAVISTAR MRD
ENGINE MENU

↑      DIAGNOSTIC TESTS      ↓
```

Press the “↓” key until the “ENGINE OFF TESTS” is shown on the screen. At this point, press “ENTER”.

```
NAVISTAR MRD
DIAGNOSTIC TESTS

↑      ENGINE OFF TESTS      ↓
```

After the “ENTER” key is pressed, the EST will cause the ECM to perform a self test.

When the test is complete, the screen will display the number of new faults found in the self test. It there are any additional faults found, press “ENTER” and the faults will be displayed. If there is more than one fault found during the test, the “↑↓” symbol will be shown on the screen. Press the “↓” key to access any additional faults.

After the “ENGINE OFF TEST” has been performed several other tests are available.

At the completion of the “ENGINE OFF TEST” press the “FUNC” key to access the “ENGINE OFF TEST MENU”.

The first option will be “ACTIVE CODES”. By selecting this option, any active codes will be displayed.

SELF TEST (ENGINE OFF)

Press the “↓” key to display other options. The next option will be “SELF TEST”. By selecting this option, the “ENGINE OFF TEST” will be repeated.

INJECTOR TEST (ENGINE OFF)

Press the “↓” key to continue. The next option is “INJECTOR TEST”. By selecting this test the ECM will exercise (Buzz) the electronic injectors. During this test it will measure the circuits as well activate the injectors. This will allow the technician to listen to the operation of the injector without the engine running. At the completion of the test, if the electronic components detect any faults they will be recorded and displayed. Also by monitoring the noise made by the injector the technician can determine if an injector does not fire electronically.

NOTE: *This test can only be done after the engine off test has been completed.*

Select the “INJECTOR TEST” then press the “ENTER” key.

```
NAVISTAR MRD
DIAGNOSTIC TESTS

↑      INJECTOR TEST      ↓
```

Depressing the “ENTER” key will start the test.

At first all the injectors are energized, a loud buzzing noise can be heard.

Next, each injector will be energized individually. This will proceed in sequence starting at number 1 cylinder and proceeding through number 8 cylinder. All eight injectors should be heard as the injectors fire.

After the injectors are fired individually the complete sequence will repeat several times.

At the end of the test, the screen will indicate if any faults were found. If faults are indicated, press the "ENTER" key. This will display any faults that were recorded. If there are multiple faults the "↑↓" symbol will appear on the screen. Press the "↓" key to display the other faults.

OUTPUT STATE TEST

The next test available is the "OUTPUT STATE TEST". This will signal the ECM to energize the output circuits for testing.

There are two modes of operation during this test. The first is "OUTPUT ARE LOW" and the other is "OUTPUTS ARE HIGH".

When in the "OUTPUTS ARE LOW" mode the ECM will pull down the output voltage to ground. This will actuate the output components that are controlled by the ECM grounding the circuits. During this test "OUTPUTS ARE LOW" will be displayed on the screen.

When in the "OUTPUTS ARE HIGH" mode the ECM will pull up the output voltage to 12 volts. This will actuate the output components that are controlled by the ECM energizing the control circuits with 12 volts. During this test "OUTPUTS ARE HIGH" will be displayed on the screen.

During this test the following components will be exercised, IDM, Enable relay, IPR (Injection Pressure Regulator), ECI (Engine Crank Inhibit Relay), EDL (Engine Data Link Relay), OWL (Oil/Water Light & Alarm), relay and WARN engine light.

To access this test press the "↓" key until "OUTPUT STATE TEST" appears on the screen. Press "ENTER" to start the test.

Press the "ENTER" key to switch from "OUTPUTS ARE LOW" to "OUTPUTS ARE HIGH". The mode will change each time the "ENTER" key is pressed.

To end the test press the "FUNC" key.

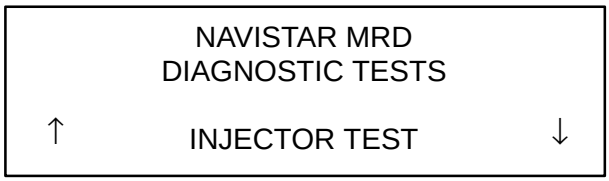
While the test is being performed the technician can measure output circuits to be certain the ECM outputs are functioning properly.

ENGINE RUNNING TEST

The "ENGINE RUNNING TEST" will test engine outputs and performance with the engine running. This will allow the technician to determine if the outputs are within proper operating specifications.

Engine running tests can only be performed with the engine above 160° F (71° C).

To access the "ENGINE RUNNING TEST", from the "DIAGNOSTIC TESTS" menu, press the "↓" key until "ENGINE RUNNING TEST" Is displayed on the screen. Press the "ENTER" key to start the test.



Pressing the "ENTER" key will **begin the test.** The ECM will raise the engine low idle and command full ICP (Injection Control Pressure). The ECM **will then** measure what the actual pressure is and compare it to the commanded value.

At the completion of the test the engine will return to normal low idle and the screen will display the number of faults found.

It there are any faults found, press the "ENTER" key to display the faults. If the "↑↓" symbol is shown, more faults are accessible. Press the "↓" key to display additional faults.

After the "ENGINE RUNNING TEST" has been completed the injector test is accessible.

INJECTOR TEST

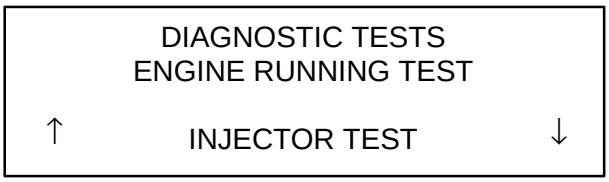
The injector test will test each cylinder's contribution. This will measure how much work is being done by each cylinder as compared to the other cylinders.

The ECM will measure this by increasing the amount of fuel delivery by five times to the injector being tested and monitoring the reduction in the **other** cylinders to maintain engine speed. If there is no reduction in fuel delivery to the other cylinders the ECM will set a fault code.

To access the "INJECTOR TEST" **from the Diagnostic Tests menu** press the "↓" key until the "INJECTOR TEST" is shown on the screen under the "ENGINE RUNNING TESTS" menu. Then press the "ENTER" key.

NOTE 1: *"ENGINE RUNNING TEST" must be performed first to access this test.*

NOTE 2: *While performing this test the engine will run rough.*



When the test is complete, the number of faults found will be displayed. If there are any faults found press the "ENTER" key to display the faults. If there is more than one fault, the "↑↓" symbol will be displayed. Press the "↓" key to display other faults.

TACH BUFFER TEST

The Tach Buffer Test checks the circuit between the ECM and VPM along with the internal buffer circuit in the VPM.

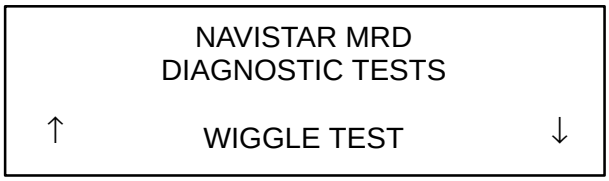
To perform this test select the "TACH BUFFER TEST" from the "ENGINE RUNNING TEST" menu.

The test must be performed with the engine speed above 1250 RPM.

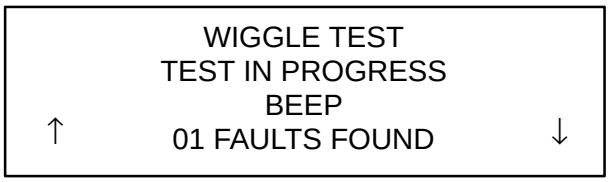
WIGGLE TEST

"WIGGLE TEST" is available under the Diagnostic Test Menu. The wiggle test is to assist the technician in finding an intermittent condition. The wiggle test will monitor both signal outputs and **inputs on a continuous** basis. Any interruption in the circuit will cause a fault.

To access "WIGGLE TEST" from the Diagnostic Test Menu, press the "↓" key until "WIGGLE TEST" is displayed on the screen. Press the "ENTER" key, to start the test.

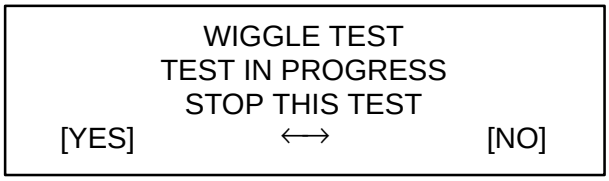


At any time during the Wiggle Test if an open or short is detected the EST will beep and the word **"BEEP" will display on the screen.**



While in the Wiggle mode, the technician can move and wiggle the wiring harness and connectors to locate the problem.

To end the test press the "FUNC" key. The message will ask "STOP THIS TEST" press the "←" key to select yes. This will end the test.



If any faults were detected, press the "ENTER" key to display the fault.

Service Tool Functions

PRO-LINK FUNCTIONS

Several options are available in the Pro-Link tool menu. To access these functions press the "→" key to select the "PRO-LINK" options. This will cause brackets [ ] to be placed around "PRO=LINK". Press the "ENTER" key to make this selection.

NAVISTAR MED SELECT DESIRED MENU		
ENGINE	⟷	[PRO-LINK]

From the tool menu press the "↓" key to display the tool functions.

CONTRAST ADJUST

From the "CONTRAST ADJUST" display press the "ENTER" key to select this option.

Use the "↑↓" keys on the Pro Link keypad to adjust the contrast of the characters on the Pro-Link display.

ENGLISH/METRIC

The Pro-Link displays in either English or Metric units. To select the feature, press the "←→" keys to select either English of Metric. Press the "ENTER" key to enter the selection.

CUSTOM DATA LIST

This selection enables the technician to design a custom data list, placing data items in the list in the order that the technician chooses to view them. When the Custom Data List is selected from the Function Menu, the following screen is displayed.

SELECT CUSTOM DATA LIST OPTION		
↑	DISPLAY STANDARD	↓

Display Standard

The Pro-Link stores in memory both the Standard Data List and one Custom Data List created by the technician. Selecting Display Standard selects the default list configuration for viewing and printing data lists. Pressing the "ENTER" key presents Diagnostic Data on the display in the Standard format for viewing.

Display Custom

Selecting Display Custom, selects the list configuration created with the Edit Custom menu selection. The Pro-Link displays Diagnostic data on the Pro-Link screen in the chosen custom format. If no custom list exists, the Standard List is displayed.

Edit Custom

Selecting Edit Custom enables the technician to configure how he wants to view Diagnostic Data on the Pro-Link screen and/or from a printer. The editing screen is shown below.

SELECT PARAMETER ↑↓ PRESS ENTER CURRENT LINE ← 1 →	
ACTIVE CODES	[NO]

The table below shows the keys used for creating the Custom Data List and the result of the key.

FUNC	Exits Edit Custom Mode
→	Scrolls up Current Line number and Parameter
←	Scrolls down Current Line
↑	Scrolls up the Parameter only, Current Line Number unchanged
↓	Scrolls down the Parameter only, Current line number unchanged
ENTER	Accepts the Current Line number and Parameter combination

To create a custom Data List:

- Select the desired data line as the Current Line number.
- Select the desired parameter to be displayed on the line.
- Press the ENTER key. No change to the data list occurs unless ENTER is pressed.
- Repeat for each Data Line.

Reset Custom

This selection resets the Custom Data list back to the Standard List form. When selected, the following screen is displayed.

```
RESET CUSTOM LIST
BACK TO STANDARD
ARE YOU SURE?
YES  ⟷  [NO]
```

No is the default action. Reset the Custom Data List to the Standard List by pressing the "←" key to Select YES, then press the "ENTER" key.

NOTE: *If the Custom Data List is reset to the Standard List form, the Custom List is lost and must be recreated.*

RESTART

Restart resets the Pro-Link to the beginning of the program. The contrast adjustment is not affected by Restart.

RS-232 SERIAL PORT

This selection allows the technician to configure the Pro-Link RS-232 serial port for either printer or terminal (personal computer) output. The screen below appears when this item is selected.

```
RS-323 SERIAL PORT
FUNCTION MENU
↑  PRINTER OUTPUT  ↓
```

This selection is used to print out diagnostic information.

The Pro-Link is set up to print to the Pro-Link Printer and no Port Setup is necessary for that printer. In order to print to a different printer, follow the instructions under Port Setup, in the Electronic Service Tool manual.

The following screen will be displayed if the "PRINTER OUTPUT" function is selected.

```
SELECT DATA TO PRINT
↑  DATA LIST  ↓
```

There are five types of data which can be printed out

DATA LIST

DIAGNOSTIC CODES

CALIBRATION DATA

SNAPSHOT DATA

REPROG PARMS

Press the "↓" key to select other options. Press "ENTER" and the selection will be printed.

Snapshot

Selecting the Snapshot option will display the following screen.

```
DO YOU WISH TO PRINT
THE COMPLETE LIST
OR A CUSTOM LIST?
[COMPLETE]  ⟷  CUSTOM
```

Complete

Choosing "COMPLETE" produces a screen as shown below.

```
SNAPSHOT PRINTOUT
SELECT FRAMES
TRIG = ###  FRAMES = ###
START = ###
```

TRIG = Frame number that contains the trigger.

FRAME = Total number of frames in Snapshot memory (a frame is one complete Data List)

START = The first frame desired to print

Selecting "COMPLETE" will print all lines of the data list. Enter the first frame desired to print at "START" and press "ENTER". Now line four will display END = # # #. Enter the last frame desired to print and press "ENTER". The tool will now print the complete data list for each of the frames that are selected.

Custom

Selecting Custom produces the following screen.

```
SELECT UP TO 6 DATA
PARAMETERS TO PRINT
USE FUNC TO QUIT
ENTER TO CONTINUE
```

Press the “ENTER” key and the following screen appears.

```
SELECT DATA TO PRINT
PRESS ENTER
COLUMN # = 1
ACTIVE CODES
```

Use the “↑↓” keys to scroll the list on line four. Choose the item desired for column 1 of the custom list, press the “ENTER” key. Line three, “COLUMN #”, advances to 2. Repeat this procedure for all six columns of data to be printed. Press the “FUNC” key when finished. The Select Frames screen appears. Select the desired frames to print and the Custom printout will begin.

SNAPSHOT

Snapshot allows the technician to record data from the Data List, for review. This can be helpful for collecting data while driving the truck or for searching for an intermittent problem.

The following functions are available for Snapshot:

- Quick Trigger
- Trigger Setup
- Data Update Rate
- Review Snapshot

Quick Trigger

The Quick Trigger function enables the technician to take a second Snapshot quickly, using the previous setting established during Trigger Setup for the first Snapshot. It is not necessary to reset the setup values for each Snapshot. Press the “ENTER” key and the data is displayed on the Pro-Link screen.

The Quick Trigger default trigger is Any Numeric Key. Press any numeric key on the Pro-Link keypad to start recording data. Press any numeric key again to stop recording data.

Trigger Setup

Trigger Setup allows the technician to configure how and when Snapshot triggers. Selecting this option displays the screen shown below.

```
SELECT SNAPSHOT
TRIGGER SOURCE

↑      ANY NUMERIC KEY      ↓
```

Four choices are available for Snapshot triggering:

- Any Numeric Key
- Any Code
- Specific PID
- Specific SID

Any Numeric Key

Choosing this option requires the technician to press any numeric key on the Pro Link keypad to activate the trigger.

Specific Code, PID and SID

When selecting a Specific Code, PID or SID a screen is displayed which enables the technician to choose the Code, PID or SID to trigger on from a list of those choices.

Setting Memory Trigger Point

Selecting any of the Trigger Setup options presents the display below.

```
DO YOU WISH TO
ADJUST THE MEMORY
TRIGGER POINT
YES        ←→        [NO]
```

NO is the default. To adjust the trigger point, use the “←” key to select YES, then press “ENTER”. Selecting YES present the following screen.

```
T INDICATES LOCATION
OR TRIGGER IN MEMORY
BEG          MID          END
[ . . . . . . . . . . . . . . T . . . . . . . . . . . . . . ]
```

Use the “←→” keys on the Pro-Link keypad to adjust the location of “T” along the line, then press “ENTER” to accept this position . When the trigger occurs, all data to the right of “T” was received after the trigger occurred or towards the end of the Snapshot, Data to the left of “T” was received before the trigger occurred or towards the beginning of the Snapshot.

Processing the Trigger

After defining all the setup functions, pressing the “ENTER” key presents the prompt on the screen, “WAITING FOR TRIGGER”.

The Pro-Link is now storing data from the ECM and waiting for the trigger condition to occur. When the trigger occurs, the prompt is displayed “PROCESSING TRIGGER”. The Pro-Link will record data in its memory buffer until full. When complete refer to “Review Snapshot”.

Review Snapshot

This function will only be displayed when there is Snapshot data in memory to view. The Snapshot should have been triggered previously and the data stored in memory. The following screen is displayed.

DATA
DATA
DATA
T = # # # C = # # # GOTO _ _ _

The “↑↓” keys are active and scroll the data up and down. The “←→” keys scroll the current frame number (C). Pressing any numeric key followed by pressing the “ENTER” key reverts to that frame number. Entering a GOTO_ _ _ frame number greater than the number of frames in memory, reverts to the highest frame in memory. Pressing the “ENTER” key without having pressed any other key presents the codes for that frame. Arrows appear on line four if there is more than one code. Pressing “ENTER” again reverts back to the Review Snapshot Data List mode. Data Update Rate

This selection gives the technician the ability to determine how often Snapshot data is updated in memory. As the time is increased, the delay between sampling frames is increased. The following screen is displayed when this option is selected.

DATA UPDATE RATE
SELECT DELAY
THEN PRESS ENTER
CURRENT = 0.1 NEW = 0.1

On the numeric keypad of the Pro-link, type in the desired delay time from within the range of 0.1 to 9.9 seconds, then press “ENTER”. The screen automatically returns to the Snapshot Function Menu screen.

GPC, Glow Plug Control - Controls the current flow to the glow plugs. Glow plug relay "ON"time is controlled by the ECM and is a function of engine coolant temperature, barometric pressure and battery voltage. "ON" time normally varies between 10 to 120 seconds. The glow plug relay will only cycle on and off repeatedly when there is a voltage condition greater than 12.5 volts.

FUEL SYSTEM GLOSSARY

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Glossary

Actuator - A device which performs work in response to an electrical signal.

Address - A specific memory location in the RAM, ROM, or KAM of the ECM. The ECM can either read information from an address or send information (write) to an address (RAM or KAM only).

Analog - A continuously variable voltage.

Analog to Digital Converter (A/D) - A circuit within the processing section of the ECM that takes an analog signal (either DC or AC) and converts it into a usable digital signal for the microprocessor.

Analog Multimeter - A meter that uses a needle to point to a number on a scale of numbers to indicate a measured value (volts, ohms, amperes). Not recommended for use on microprocessor systems because of the possibility of excessive current due to the low impedance of the meter.

ATA Data Link - A serial data link specified by the American Trucking Association and the SAE.

Background Manager - The portion of the computer that performs “housekeeping duties”. Typically the Background Manager controls low priority items or items that occur at a slower rate.

BARO Barometric Pressure Sensor - A variable capacitance sensor which, when supplied with a 5 volt reference signal from the ECM, produces a linear analog voltage signal indicating pressure.

Calibration - The data values used by the strategy to solve equations and make decisions. Calibration values are stored in the ROM as scalars, functions and tables. Calibration values are input into the processor during programming to allow for the engine to operate within certain parameters.

CI, Cylinder identification - A signal from the ECM to the IDM that identifies the position of the cylinders of the engine.

Check Engine Lamp - Lamp in the dash that comes on when selected fault codes are set or when the ECM is utilizing FMEM strategy. Fault codes can be read as flash codes through the CHECK ENGINE lamp. To access the flash codes, the STI (Self Test Input “Engine Diagnostics”) switch is depressed and held momentarily while the ignition switch is placed in the “ON’ position. This will cause the CHECK ENGINE lamp to flash any fault codes which were stored while operating the engine.

CLS, Coolant Level Switch - A switch style sensor used to indicate low coolant level.

CMP, Camshaft Position Sensor - A Hall effect sensor used to indicate engine speed and camshaft position. Speed is indicated by the number of vanes counted per revolution. Camshaft position is indicated by a single narrow vane which indicates #1 cylinder position or a wide vane in dual sync application that indicates #4 cylinder.

Continuous Test - A function of the ECM in which the inputs and outputs of the ECM are continuously monitored to assure that the readings are within set limits.

DCL, Data Communication Link - A serial communication link between the ECM and the VPM.

Disable - A type of computer decision which results in an system being deactivated and not allowed to operate.

Driver - A transistor in the output section of the ECM that is used to turn on or off various actuators in the system.

Duty Cycle Signal - A type of wave signal that has a controlled on/off time measure
from 0% to 100%. Normally used to control solenoids.

DVOM Digital Volt Ohm Meter - A meter that uses a digital display to indicate a measured value. Preferred for use on microprocessor systems, because a DVOM has a very high internal impedance and will not load down the circuit being measured.

ECM, Electronic Control Module - The housing which contains the micro computer, Vref regulator, input conditioners and output drivers.

ECM Power Relay - Relay which supplies or removes power to the ECM.

ECT, Engine Coolant Temperature Sensor - A thermistor type sensor which indicates engine temperature.

EF IDM Feedback - A communication line from the IDM to the ECM. In run mode, the signal on EF mirrors the FDCS signal received by the ECM from the IDM. EF extensions will be used to identity detected problems with individual injectors.

EFRC, Engine Family Rating Code - A code readable in the calibration list of the VPM with the EST service tool that identifies the horsepower and emission calibration of the engine.

Engine Off Test - A self test operation that is performed with the ignition switch in the “ON” position with the engine off.

Engine Running Test - Self test operation that is performed with the engine running.

EOP, Engine Oil Pressure sensor - A switch type sensor used to indicate low oil pressure.

EST Electronic Service Tool - The scan tool used for accessing diagnostics and programing the MerCruiser 7.3 D-Tronic electronic control system.

EWL - Engine Warning Light Circuit

FDCS, Fuel Demand Command Signal - Command signal generated by the ECM and sent to the IDM which controls when an injector is energized (opened) and how long the injector remains energized (open). This signal determines when and how much fuel the injector delivers to the combustion chamber.

FMEM, Failure Modes Effects Management - An alternate control strategy devised to reduce the adverse effects that can be caused by a system failure. Should a sensor fail, the ECM substitutes a good sensor signal or assumed sensor value in its place. The WARN ENGINE Lamp is then lit to alert the driver to take the engine in for service.

Foreground Manager - That portion of the computer that controls the primary engine control functions. The foreground manager responds to external events quickly to maintain correct engine performance under a variety of conditions. Typically the foreground manager controls high priority items.

Function - An input value to a computer which the computer solves for an output.

Fusible Link - A wire designed to melt if more than a specified amount of electrical current flows through it.

GPC, Glow Plug Control - Controls the current flow to the glow plugs. Glow plug relay "ON"time is controlled by the ECM and is a function of engine coolant temperature, barometric pressure and battery voltage. "ON" time normally varies between 10 to 120 seconds. The glow plug relay will only cycle on and off repeatedly when there is a voltage condition greater than 12.5 volts.

GPL - Glow Plug Wait Lamp

GPR, Glow Plug Relay - ECM controlled relay which supplies power to the glow plugs.

Hall Effect Sensor - A Hall Effect sensor generates a digital on/off signal that indicates speed and also engine timing. The signal is created by a switching action caused by the passing of a vanes thru a positive and negative voltage potential. When the vane is between this potential a signal is created. When the gap is between this potential is open, no signal is generated. The wider the vane the longer the duty cycle of the signal, the narrower the vane the shorter the duty cycle of the signal. A narrow vane is used to indicate the position of #1 cylinder and a wide vane to indicate the position of #4 cylinder. A Hall Effect sensor has three connections ground, Vref, signal.

High Speed Digital Inputs - Inputs to the ECM that are from a sensor that generates varying frequencies. Examples of high speed digital input sensors are engine speed, and Manifold Absolute Pressure (MAP) sensors.

IAT, Intake Air Temperature sensor - A thermistor style sensor used to indicate intake air temperature.

ICP, Injector Control Pressure Sensor - A transducer style sensor used to indicate Injection Control Pressure.

IDM, Injection Driver Module - Is an electronic unit which has the primary function of an electronic distributor for the injectors. It also is the power supply for the injectors. It supplies 115 volts dc @ 7 amps to the injectors.

Impedance - A form of opposition to AC current flow measured in Ohms.

Injection Control Pressure - High lube oil pressure generated by a high pressure pump/pressure regulator used to hydraulically actuate the fuel injectors.

Input Conditioner - A device or circuit that conditions or prepares an input signal for use by the microprocessor.

IPR, Injection Control Pressure Regulator - An ECM controlled pulse width modulated regulator valve which regulates injection control oil pressure.

KAM, Keep Alive Memory - Is a memory location in the microprocessor which allows the ECM to store information on input failures, identified in normal operations for use in diagnostic routines. Keep Alive Memory can also store alternate calibration parameters generated by the FMEM strategy in event of sensor failure or wear. KAM memory is volatile and will be lost if power is disconnected.

KAMPWR - The circuit that continuously supplies KAM memory with 12 volts to prevent the loss of KAM memory.

Low Speed Digital Inputs - Are switched sensor inputs that generate an on/off (high/low) signal to the ECM. The input supplied to the ECM from the sensor could be from a high input source switch (usually 12 or 5 volts) or could be from a grounding type switch which grounds the signal from a current limiting resistor internal to the ECM and creates a low signal. (0 volts)

MAP, Manifold Absolute Pressure - A MAP sensor is a sensor that generates a digital frequency that indicates manifold boost pressure or vacuum. The signal is created by switching action caused by manifold pressure on a diaphragm connected to a capacitor circuit in the sensor. The digital frequency increases as pressure increases. A MAP sensor has three connections, signal return (grd), MAP signal and Vref.

Microprocessor - An integrated circuit within a micro computer which controls information flow within the computer.

Normally Closed - Refers to a switch or a solenoid that is closed when no control force is acting on it.

Normally Open - Refers to a switch or solenoid that is open when no control force is acting on it.

On Demand Test - A self test which the technician initiates, and is run from a program in the processor.

OCC, Output Circuit Check - An “On Demand’ test performed during an “Engine Off’ self test that tests the continuity of selected actuators.

Output State Check - A “On Demand” test selected by the technician which forces the processor to activate actuators “High or Low” for additional diagnostics.

OWL - Oil/Water Light and Alarm

Potentiometer - Is an electro-mechanical device (variable voltage divider) which senses the position of a mechanical component. Potentiometers have three connections, Vref, Signal out (wiper) and ground.

PROM - Programmable Read Only Memory

Pulse Width - The length of time an actuator, such as an injector remains energized.

RAM, Random Access Memory - A type of memory that is used to store information. Information can be written to and read from the RAM. Input information such as current engine speed or temperature would be stored here to be compared to values stored in the ROM. All memory in the RAM is lost when the ignition switch is turned off.

Read - A computer operation where information is retrieved from the memory.

RFI - Radio Frequency Interference

ROM, Read Only Memory - A type of memory that is used to store information permanently. Information can not be written to the ROM memory. Operating strategies and calibration tables are the type of information most commonly stored in the ROM.

Sampling - The act of periodically collecting information, as from a sensor. A microprocessor samples inputs from various sensors in the process of controlling a system.

Scalar - A single numerical value that is assigned a label and is used as a calibration parameter. This value can be multiplied, divided, added or subtracted to a given input.

SIG GRD, Signal Ground - The common ground wire to the ECM in wire harness for the sensor inputs.

STI, Self Test Input “Engine Diagnostics” Switch - Diagnostic switch located on vessel dash used to activate Self Test Input engine diagnostics.

Strategy - A plan or set of operating instructions that the microprocessor follows in order to achieve a desired goal. Strategy is the computer program itself, including all equations and decision making logic. Strategy is always stored in the RAM an thus cannot be changed during calibration.

STOP - Stop Engine Lamp

Switch Sensors - Switch sensors are used to indicate position, levels or pressures. The signal of a switch sensor is a digital signal created by either the opening or closing a switch. The on or off signal can indicate position as in the case of a clutch switch, lever as in the case of a coolant level switch, or pressure as in the case of a low oil pressure switch. A switch sensor normally has two connections signal return (Grd) and the signal. A switch sensor is considered a low speed digital signal input.

TAC, Tachometer Output Signal - Engine speed signal from the ECM to the VPM.

Table - Devices that a computer uses to take two different inputs and solve for an output.

Thermistor - Sensor used to determine temperature. A thermistor changes its resistance value in relation to temperature change. Increasing temperature results in decreasing resistance, decreasing temperature results in increasing resistance. The thermistor in conjunction with a current limiting resistor in the ECM forms a voltage divider that provides a voltage signal that indicates temperature. Since the top half of the voltage divider is the current limiting resistor and is internal to the ECM a thermistor sensor only has two connections, signal return and ground.

Threshold Value - A value stored in the ROM portion of the ECM. This value is compared to the value of a particular sensor provided to the ECM during the continuous self-test. If the value is not within the parameters of the threshold value, a service code is entered into the KAM.

TPS, Throttle Position Sensor - A potentiometer style sensor that indicates the operator's throttle position.

Transducers (load cells) - Transducers are used to sense pressure. Their function is very similar to potentiometers. The 5 volt reference signal is changed by the internal circuitry of the sensor into an analog voltage that indicates pressure. A transducer sensor has three connections Vref, signal and ground.

Transition - Changing from one value or condition to another, such as from positive to negative in an electronic circuit.

UVC, Under Valve Cover - A combination valve cover gasket and harness containing fuel injector and glow plug wiring.

VIGN, Voltage Ignition - Voltage supplied by the ignition switch when the key is in the "ON" position.

VPM, Vessel Personality Module - A module which identifies to the ECM the individual parameters for the system being used.

V Ref Reference Voltage - A five volt reference supplied by the ECM to operate the engine sensors.

VBAT - Battery voltage. (See VPWR)

VPWR - Battery voltage. (See VBAT)

Write - A computer operation where information is sent to and stored in memory.

Abbreviations And Acronyms

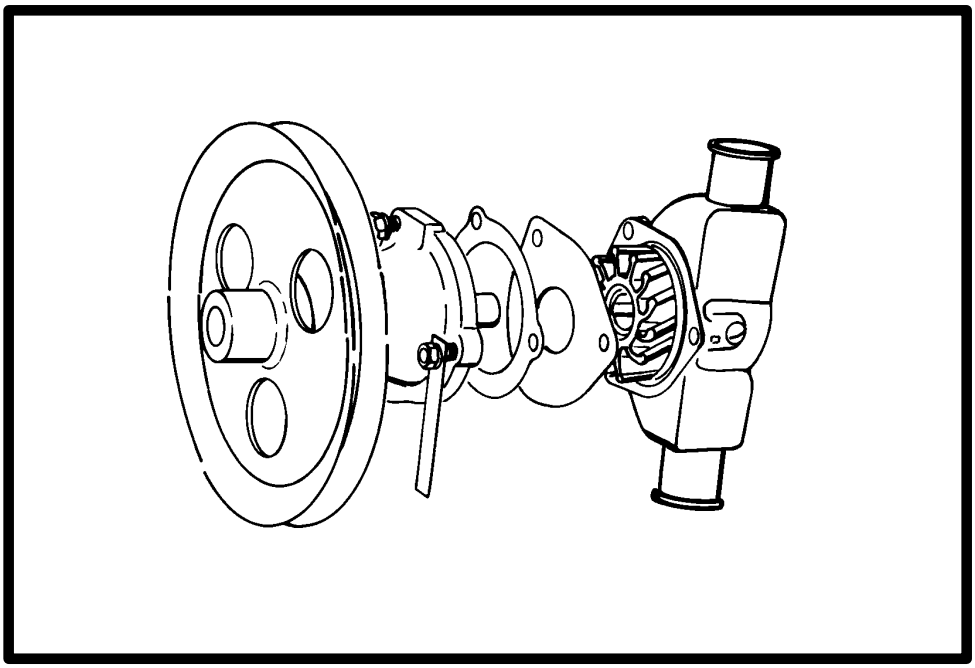
ATS	AMBIENT TEMPERATURE SENSOR
BARO	BAROMETRIC PRESSURE SENSOR
CMP	CAMSHAFT POSITION SENSOR
ECM	ELECTRONIC CONTROL MODULE
ECT	ENGINE COOLANT TEMPERATURE SENSOR
EOP	ENGINE OIL PRESSURE SENSOR
FDCS	FUEL DELIVERY COMMAND SIGNAL
HEUI	HYDRAULICALLY ACTUATED, ELECTRONICALLY CONTROLLED UNIT INJECTORS
ICP	INJECTOR (OIL) CONTROL PRESSURE SENSOR
IDM	INJECTOR DRIVER MODULE
IPR	INJECTOR (OIL) PRESSURE REGULATOR
IDM	INJECTION DRIVE MODULE
MAP	MANIFOLD ABSOLUTE PRESSURE SENSOR
TPS	THROTTLE POSITION SENSOR
UVC	UNDER VALVE COVER
VOP	VALVE OPENING PRESSURE

Conversion Table

Inch Fractions and Decimals to Millimeter Equivalents

Inches			Inches			Inches			Inches		
Fract.	Dec.	mm	Fract.	Dec.	mm	Fract.	Dec.	mm	Fract.	Dec.	mm
—	.0004	.010	—	.3000	7.620	—	.7874	20.000	—	1.969	50.0
—	.0010	.025	5/16	.3125	7.938	51/64	.7696	20.241	2	2.000	50.8
—	.0039	.100	—	.3150	8.000	13/16	.8125	20.638	2-1/8	2.125	54.0
—	.0050	.127	21/64	.3281	8.334	—	.8268	21.000	—	2.165	55.0
—	.0079	.200	—	.3346	8.500	53/64	.8281	21.034	2-1/4	2.250	57.2
—	.0098	.250	11/32	.3438	8.731	27/32	.8438	21.431	—	2.362	60.0
—	.0100	.254	—	.3543	9.000	55/64	.8594	21.828	2-3/8	2.375	60.3
—	.0118	.300	23/64	.3594	9.128	—	.8662	22.000	2-1/2	2.500	63.5
1/64	.0156	.397	—	.3740	9.500	7/8	.8750	22.225	—	2.559	65.0
—	.0157	.400	3/8	.3750	9.525	57/64	.8906	22.622	2-5/8	2.625	66.7
—	.0197	.500	25/64	.3906	9.922	—	.9000	22.860	2-3/4	2.750	69.9
—	.0236	.600	—	.3937	10.000	—	.9055	23.000	—	2.756	70.0
—	.0250	.635	—	.4000	10.160	29/32	.9063	23.019	2-7/8	2.875	73.0
—	.0276	.700	13/32	.4062	10.319	59/64	.9219	23.416	—	2.953	75.0
—	.0295	.750	—	.4134	10.500	15/16	.9375	23.813	3	3.000	76.2
1/32	.0313	.794	27/64	.4219	10.716	—	.9449	24.000	—	3.150	80.0
—	.0315	.800	—	.4331	11.000	61/64	.9531	24.209	3-1/4	3.250	82.6
—	.0354	.900	7/16	.4375	11.113	31/32	.9688	24.606	—	3.346	85.0
—	.0394	1.000	29/64	.4531	11.509	—	.9843	25.000	3-1/2	3.500	88.9
3/64	.0469	1.191	15/32	.4688	11.906	1	1.0000	25.400	—	3.543	90.0
—	.0472	1.200	—	.4724	12.000	—	1.0240	26.000	—	3.740	95.0
—	.0500	1.270	31/64	.4844	12.303	1-1/16	1.0620	26.988	3-3/4	3.750	95.3
—	.0551	1.400	—	.4921	12.500	—	1.0630	27.000	—	3.937	100.0
—	.0591	1.500	1/2	.5000	12.700	—	1.1020	28.000	4	4.000	101.6
1/16	.0625	1.588	—	.5118	13.000	1-1/8	1.1250	28.575	—	4.331	110.0
—	.0669	1.700	33/64	.5156	13.097	—	1.1420	29.000	4-1/2	45.00	114.3
—	.0750	1.905	17/32	.5326	13.494	—	1.1810	30.000	—	4.724	120.0
5/64	.0781	1.984	—	.5315	13.500	1-3/16	1.1880	30.160	5	5.000	127.0
—	.0787	2.000	35/64	.5469	13.891	—	1.2210	31.000	—	5.118	130.0
—	.0906	2.300	—	.5512	14.000	1-1/4	1.2500	31.750	5-1/2	5.500	139.7
3/32	.0938	2.381	9/16	.5625	14.288	—	1.2600	32.000	—	5.512	140.0
—	.0984	2.500	—	.5710	14.500	—	1.2990	33.000	—	5.906	150.0
—	.1000	2.540	37/64	.5781	14.684	1-5/16	1.3120	33.340	6	6.000	152.4
—	.1024	2.600	—	.5906	15.000	—	1.3390	34.000	—	6.299	160.0
7/64	.1093	2.776	19/32	.5938	15.081	1-3/8	1.3750	34.930	6-1/2	6.500	165.1
—	.1181	3.000	—	.6000	15.240	—	1.3780	35.000	7	7.000	177.8
1/8	.1250	3.175	39/64	.6094	15.478	—	1.4170	36.000	—	7.087	180.0
—	.1378	3.500	—	.6103	15.500	1-7/16	1.4380	36.510	7-1/2	7.500	190.5
9/64	.1406	3.572	5/8	.6250	15.875	—	1.4570	37.000	—	7.874	200.0
5/32	.1563	3.969	—	.6299	16.000	—	1.4960	38.000	8	8.000	203.2
—	.1575	4.000	41/64	.6406	16.272	1-1/2	1.5000	38.100	8-1/2	8.500	215.9
11/64	.1719	4.366	—	.6496	16.500	—	1.5350	39.000	—	8.661	220.0
—	.1772	4.500	21/32	.6563	16.669	1-9/16	1.5620	39.690	9	9.000	228.6
3/16	.1875	4.763	—	.6693	17.000	—	1.5750	40.000	—	9.449	240.0
—	.1969	5.000	43/64	.6719	17.066	—	1.6140	41.000	9-1/2	9.500	241.3
—	.2000	5.080	11/16	.6875	17.463	1-5/8	1.6250	41.280	—	9.843	250.0
13/64	.2031	5.159	—	.6890	17.500	—	1.6540	42.000	10	10.000	254.0
—	.2165	5.500	—	.7000	17.780	1-11/16	1.6880	42.860	—	10.236	260.0
7/32	.2188	5.556	45/64	.7031	17.859	—	1.6930	43.000	11	11.000	279.4
15/64	.2344	5.953	—	.7087	18.000	—	1.7320	44.000	—	11.024	280.0
—	.2362	6.000	23/32	.7188	18.256	1-3/4	1.7500	44.450	—	11.811	300.0
1/4	.2500	6.350	—	.7283	18.500	—	1.7720	45.000	12	12.000	304.8
—	.2559	6.500	47/64	.7344	18.653	—	1.8110	46.000	13	13.000	330.2
17/64	.2656	6.747	—	.7480	19.000	1-13/16	1.8130	46.040	—	13.780	350.0
—	.2756	7.000	3/4	.7500	19.050	—	1.8500	47.000	14	14.000	355.6
9/32	.2813	7.144	49/64	.7656	19.447	1-7/8	1.8750	47.630	15	15.000	381.0
—	.2953	7.500	—	.7677	19.500	—	1.8900	48.000	—	15.748	400.0
19/64	.2969	7.541	25/32	.7813	19.844	—	1.9290	49.000	16	16.000	406.4

COOLING SYSTEM



6
A

SEAWATER COOLED SECTION

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Torque Specifications

Item/Fastener Location	Lb. Ft. (N•m)	Lb. In. (N•m)
Aftercooler End Cap	30 (41)	
Aftercooler to Manifold	30 (41)	
Alternator Brace to Alternator		192 (28)
Alternator to Mounting Bracket	35 (48)	
Drain Plugs (Note)	Securely	
Heat Exchanger End Cap		72 (8)
Heat Exchanger to Bracket	30 (41)	
Hose Clamps	Securely	
Power Steering Pump Brace to Block	30 (41)	
Power Steering Pump Bracket	30 (41)	
Pulleys	Securely	
Seawater Pump Bracket to Block	30 (41)	
Seawater Pump Housing		120 (14)
Seawater Pump to Bracket	35 (48)	120 (14)
Thermostat Housing	30 (41)	
Thru-Hull Pickup Nut	30 (41)	
Water Temperature Sender	20 (27)	

NOTE: Coat threads with Quicksilver Perfect Seal before installing.

Lubricants/Sealants

Item/Description	Part Number
Special Lubricant 101	92-13872A1
Quicksilver Perfect Seal	92-34227--1
Loctite Master Gasket	92-12564--1
Gasket Sealer	92-72592--1
Loctite Pipe Sealant with Teflon	Obtain Locally

Special Tools

Item/Description	Part Number
Heat Exchanger Cleaning Brush Can be obtained from: Schaefer Brush Manufacturing Company 117 West Walker Street Milwaukee, WI 53204 U.S.A.	01299

Specifications

Capacity

System Capacity	
Model	**U.S. Gal. (L) (Approximate)**
All	15 (14.1)

Seawater Pump

Seawater Pump Delivery Rates	
Engine R.P.M.	**U.S. Gal. (L)**
1000	10
2000	20
3000	30
3400	34

Seawater Pickup Connections

SEAWATER PICKUP HOSE

Seawater Pickup Hose Size Requirement	
Model	**Minimum Diameter In. (mm)**
All	1-1/2 (38)

SEACOCK (WATER INLET VALVE), IF SO EQUIPPED

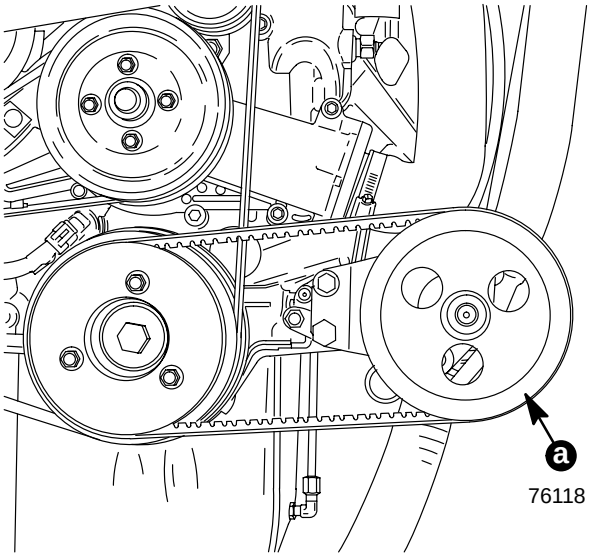
Seacock Size Requirement	
Model	**Minimum Diameter In. (mm)**
All	1-1/2 (38)

SEA STRAINER

Sea Strainer Flow Requirement	
Model	**Flow Rate Per Minute U.S. Gal. (L) (Minimum)**
All	40 (150)

Identification

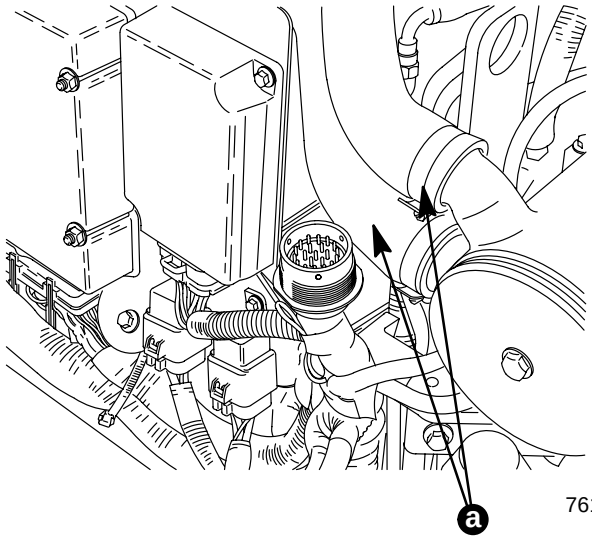
Seawater Pump



a - Seawater Pump

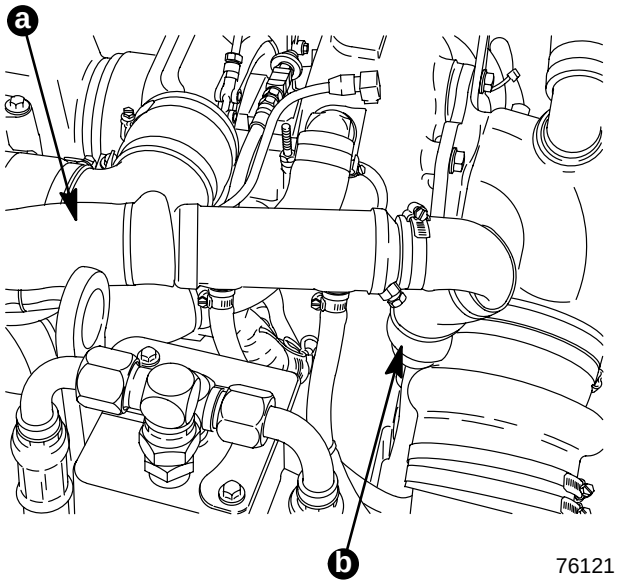
Seawater System Hose Connections

Connections At Heat Exchanger



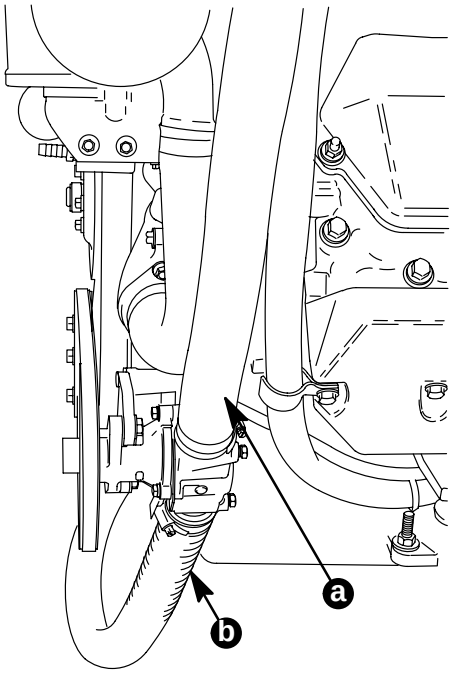
a - Hoses On Starboard Side

Connections At Power Steering Cooler



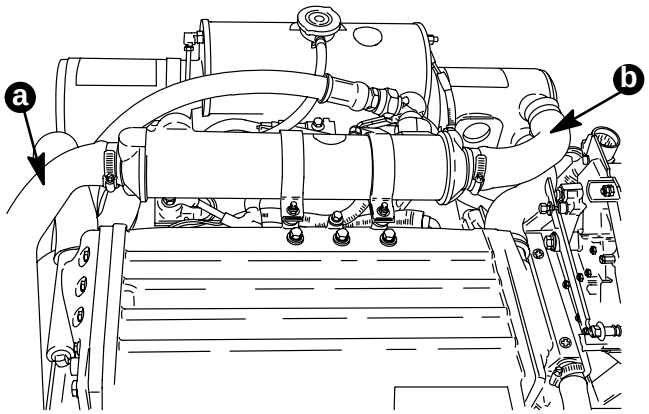
a - Hose From Oil Cooler
b - Hose To Turbocharger

Connections At Seawater Pump



a - Hose To Heat Exchanger
b - Inlet Hose

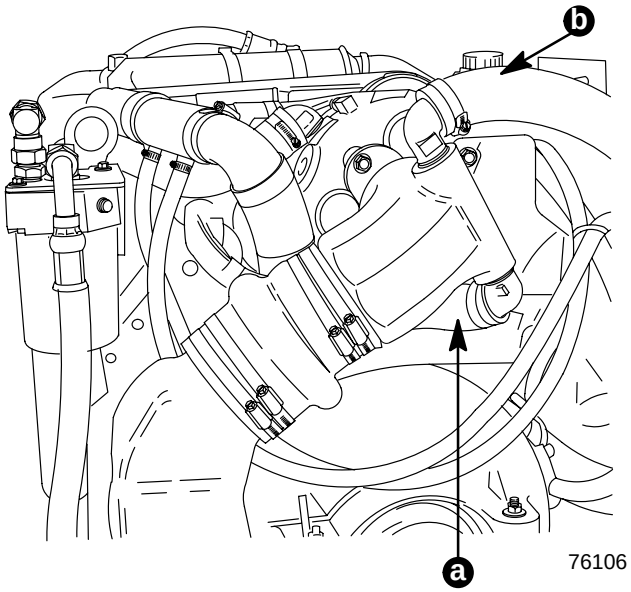
Connections Oil Cooler



76123

a - Hose To Power Steering Cooler
b - Hose From Heat Exchanger

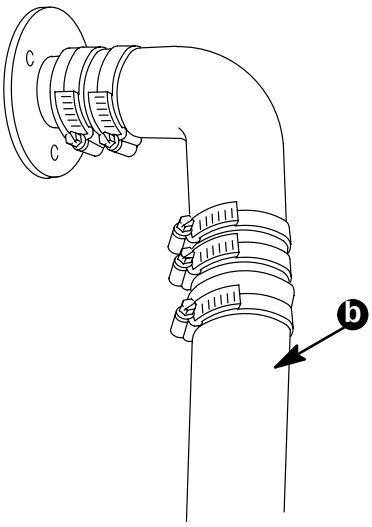
Connections At Turbo-Charger



76106

a - Hose From Power Steering Cooler
b - Hose To Overboard Discharge Fitting

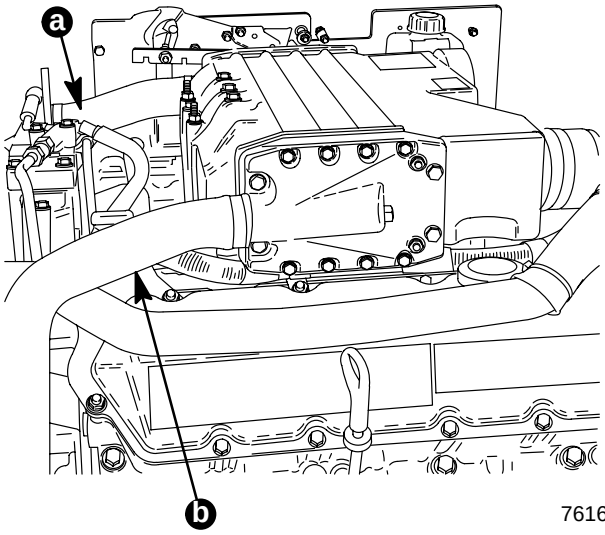
Connections At Overboard Discharge Fitting



76139

a - Hose From From Turbocharger

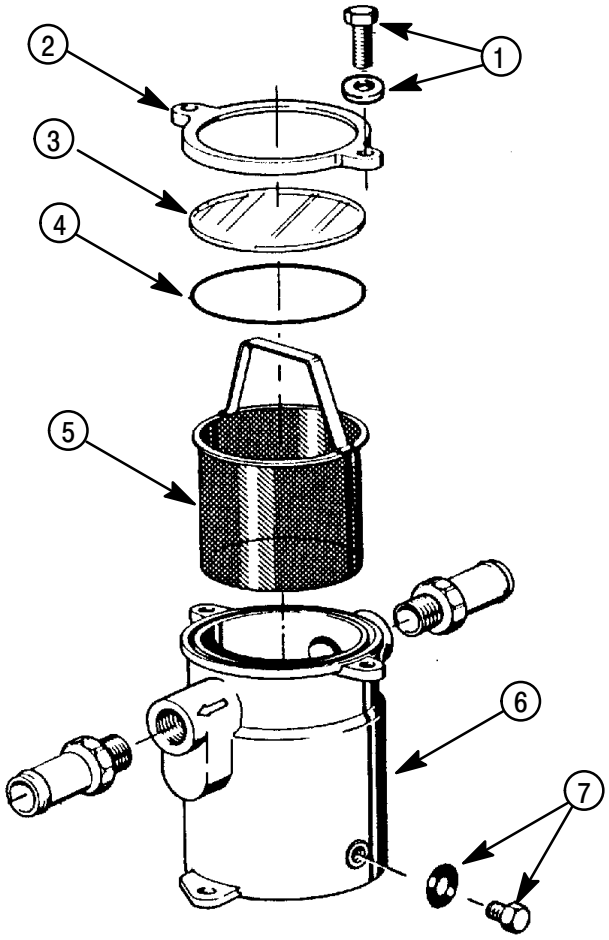
Connections At Aftercooler



76160

a - Hose To Heat Exchanger
b - Hose From Seawater Pump

Sea Strainer

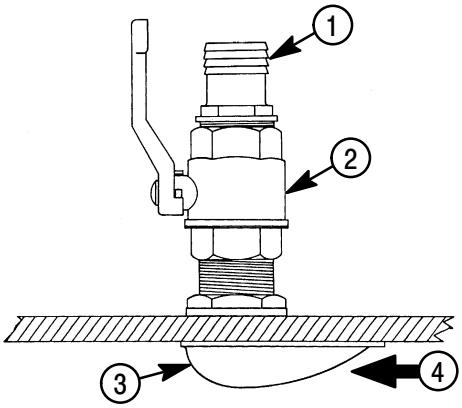


72673

Quicksilver Seawater Strainer Shown - Others Similar

1 - Screws and Washers
2 - Cover
3 - Glass
4 - Gasket
5 - Strainer
6 - Housing
7 - Drain Plug and Sealing Washer

Thru-Hull Pickup and Seacock



70355

Quicksilver Components Shown - Other Similar

1 - Hose Connector [1-1/2 In. (38 mm) I.D.] to Seawater-Strainer Inlet
2 - Seacock [1-1/2 In. (38 mm)] Brass Ball or Gate Valve
3 - Seawater Pickup
4 - Direction of Seawater Flow

Seawater Inlet Recommendations

Transom Mounted or Thru-Hull Seawater Pickup and Hose

Water pickup must be large enough to permit sufficient water flow to engine seawater pickup pump for adequate engine cooling [40 gal. per min. (150 L per min.) minimum]. Pickup also must supply a positive head while underway.

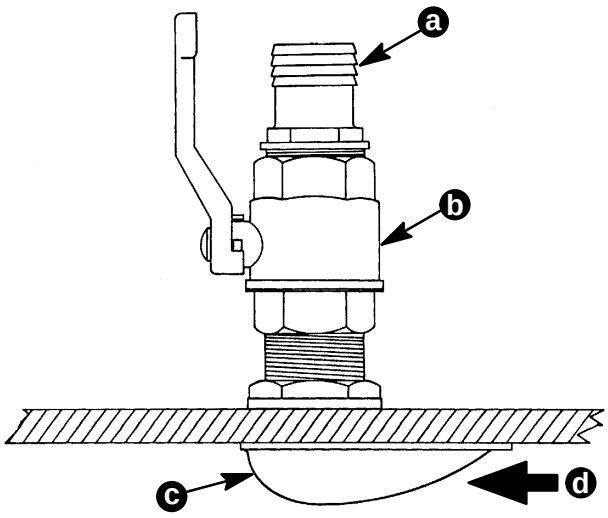
⚠CAUTION

Do not install water pickup directly in line with propeller, as pickup may create turbulence and allow air to flow into the "propeller slipstream." This will cause propeller ventilation and will adversely affect boat performance.

Water pickup should be located as close to seawater system inlet or strainer as possible and in an area where an uninterrupted, solid stream of water will flow past when boat is underway. Connect water pickup to seawater pickup pump inlet with 1-1/2 in. (38 mm) I.D. wire reinforced hose of adequate wall thickness to prevent it from collapsing from pump suction. Be sure to secure hose connections with hose clamps.

Seacock (Seawater Inlet Valve)

If a seacock is being used, it must be installed between water pickup and seawater pickup pump (or sea strainer), to allow operator to shut off the seawater in case of a leak or when boat is not in use. This will allow the operator to flush or drain the engine, or clean the sea strainer while boat is in the water. Seacock used must have an internal cross-sectional area equal to or greater than hose to prevent restricting water flow. Install seacock in an area where it will be easily accessible and self-supporting to prevent hose fatigue.



70355

a - Hose Connector [1-1/2 In. (38 mm) I.D.] to Seawater Pump Inlet
b - Seacock [1-1/2 In. (38 mm)] Brass Ball or Gate Valve
c - Seawater Pickup
d - Direction of Seawater Flow

Seacock (with Thru-Hull Pickup Shown)

Sea Strainer

If boat is equipped with a sea strainer, it must be of sufficient size to ensure that an adequate supply of water is maintained for engine cooling. Install seawater strainer in an area where it will be easily accessible for inspection and cleaning. Strainer should be installed in water inlet hose after water inlet valve to allow operator to shut off water when cleaning strainer.

Seawater Pickups

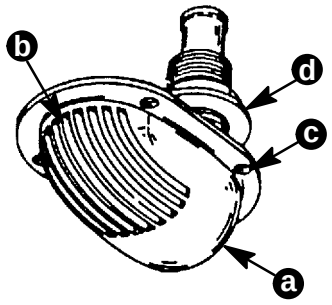
NOTICE

Refer to manufacturer's instructions for information on removal and installation of other than Quicksilver Seawater Pickups.

IMPORTANT: Seal the inside edges of any hole made through the hull with a suitable sealant to prevent water absorption and deterioration.

Thru-Hull Mounted

(Quicksilver Part Number: 68670A2)



72639

a - Seawater Pickup
b - Seawater Inlet Slots (MUST Face Forward - Parallel with-Water Flow
c - Mounting Screw Holes (if so designed)
d - Nut

Quicksilver Thru-Hull Seawater Pickup Shown

1. Seal inside edges of 1-3/4 in. (44 mm) hole in hull using a suitable sealer.
2. Apply marine caulking (sealer) to mounting surface on seawater pickup where hull contact will occur when installed.
3. Ensure slots in seawater pickup are facing forward (toward bow of boat) and install seawater pickup through hull. The slots must be parallel with flow of water.
4. Fasten pickup with four appropriate mounting screws (if so designed).
5. Apply marine caulking as needed inside boat. Apply Loctite to threads of nut and install on pickup on inside of boat and torque nut to 30 lb. ft. (41 N•m).

NOTE: *If pickup being installed does not have mounting screws on underside where mounted to hull, be certain, after nut is torqued, that slots are still facing forward.*

Sea Strainer (Quicksilver)

NOTICE

Refer to manufacturer's instructions for information on removal and installation of other than Quicksilver Sea Strainer.

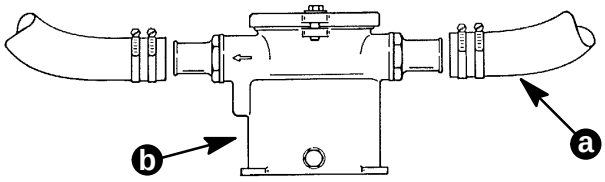
Removal

⚠ CAUTION

If boat is in water while working on seawater strainer, close seacock, if so equipped. If boat is not equipped with a seacock, remove and plug seawater inlet hose to prevent a siphoning action that may occur, allowing seawater to flow from the drain holes or removed hoses and enter boat.

IMPORTANT: Be certain engine is off and cooling system is cold.

1. Follow "a" or "b" instructions:
   a. **Models Equipped with Seacock:**
      (1) Close seacock (seawater inlet valve).
      (2) Disconnect seawater inlet hose from seawater strainer.

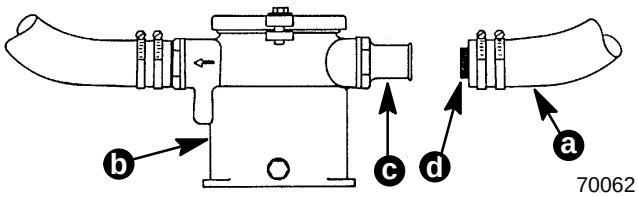


72691

a - Seawater Inlet Hose
b - Seawater Strainer

b. **Models without Seacock:**

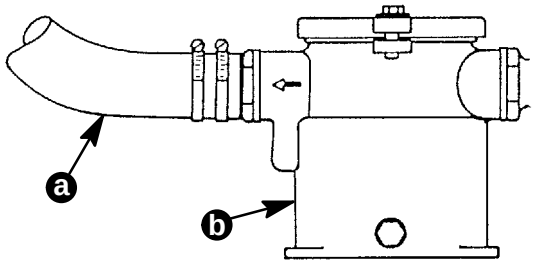
(1) Disconnect seawater inlet hose from seawater strainer inlet and plug seawater inlet hose.



70062

a - Seawater Inlet Hose
b - Seawater Strainer
c - Seawater Strainer Inlet
d - Plug

2. Remove outlet hose. Drain into a suitable container.



72643

a - Seawater Outlet Hose
b - Seawater Strainer

3. Remove mounting bolts. Remove strainer.

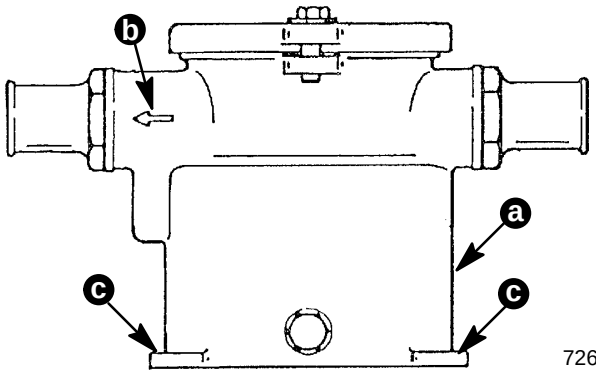
Installation

IMPORTANT: Mount seawater strainer in a vibration-free location. Never mount it on the engine or transmission. Hoses must not be kinked or allowed to come in contact with hot or moving engine or transmission parts.

1. Mount seawater strainer.

   Arrow must point toward seawater pump.

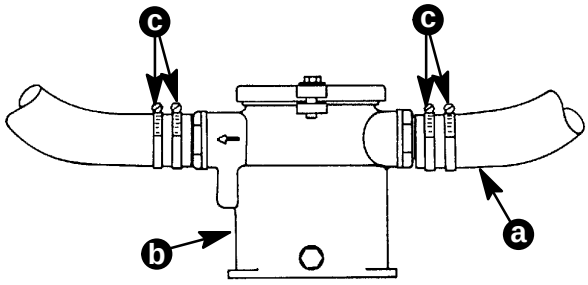
   Tighten mounting bolts securely.



72644

a - Seawater Strainer
b - Arrow
c - Mounting Bolt Hole Location (Bolts Not Shown)

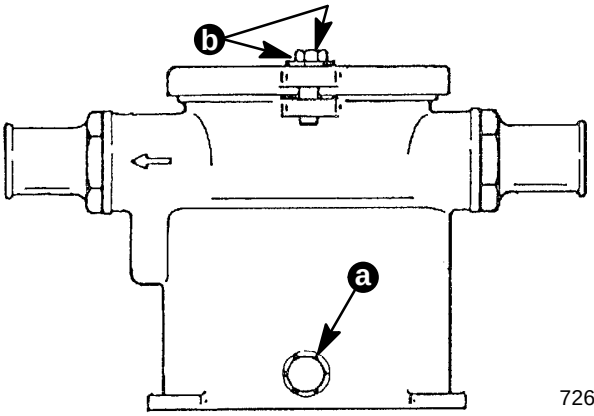
2. Install inlet and outlet hoses. Use two hose clamps on each hose connection. Tighten clamps securely.



72645

a - Seawater Inlet Hose
b - Seawater Strainer
c - Double Hose Clamps

3. Check drain plug and lens cover bolts. Tighten securely. Do not over-tighten cover bolts or cover may warp and leak water into boat.



a - Drain Plug
b - Lens Cover Bolts (2, One Hidden in This View)

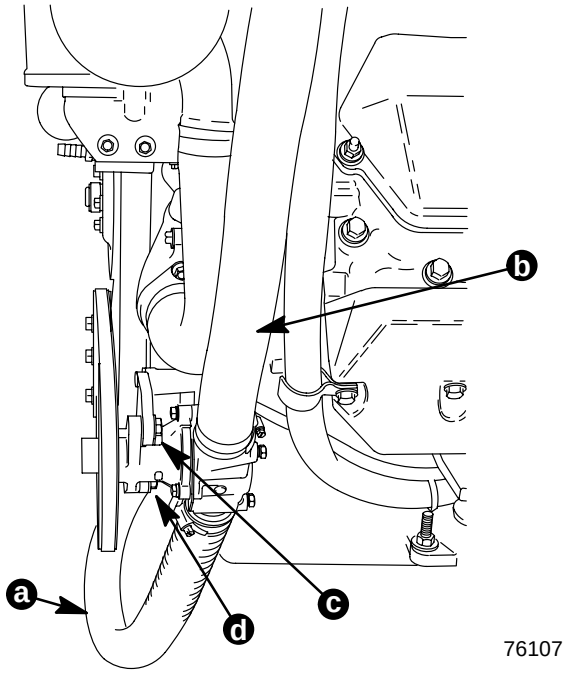
Seawater Pickup Pump

Maintenance

Whenever insufficient water flow is suspected, seawater pickup pump should be disassembled and inspected.

Removal

1. Drain seawater side of cooling system. Refer to “Draining” as outlined later in this section.
2. Remove inlet and outlet hose after draining the seawater cooling system.
3. Loosen the mounting and tensioning bolts. Remove the drive belt.
4. Remove the mounting and tensioning bolts. Remove the seawater pump from its mounting bracket.

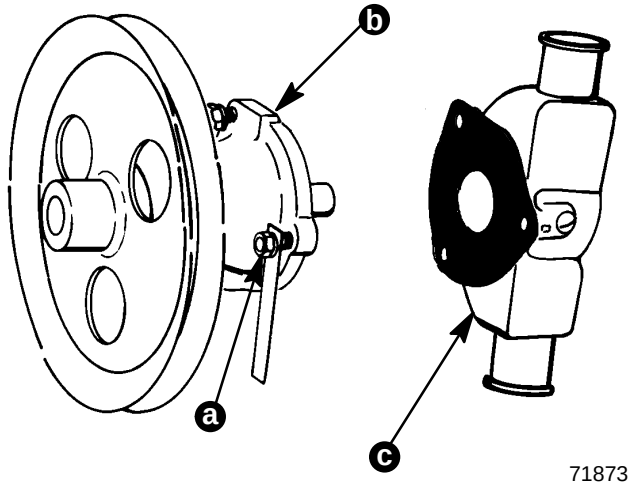


a - Inlet Hose
b - Outlet Hose
c - Mounting Bolt
d - Tensioning Bolt

Repair

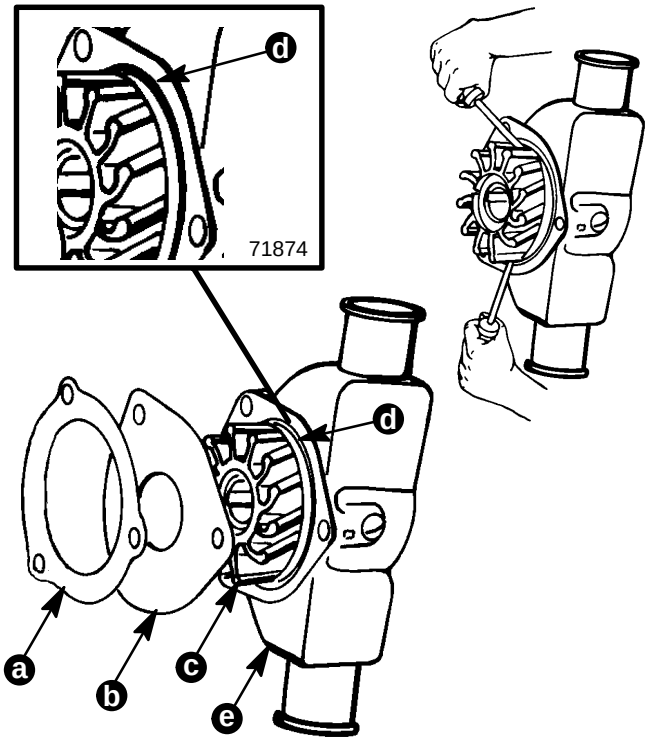
DISASSEMBLY

1. Remove cover mounting screws and washers. Remove cover from pump body.



a - Cover Screws and Washers (3)
b - Cover
c - Pump Housing

2. Remove gasket, pump plate, O-ring seal, and impeller from pump body.



a - Gasket
b - Pump Plate
c - Impeller
d - O-ring
e - Pump Housing

CLEANING AND INSPECTION

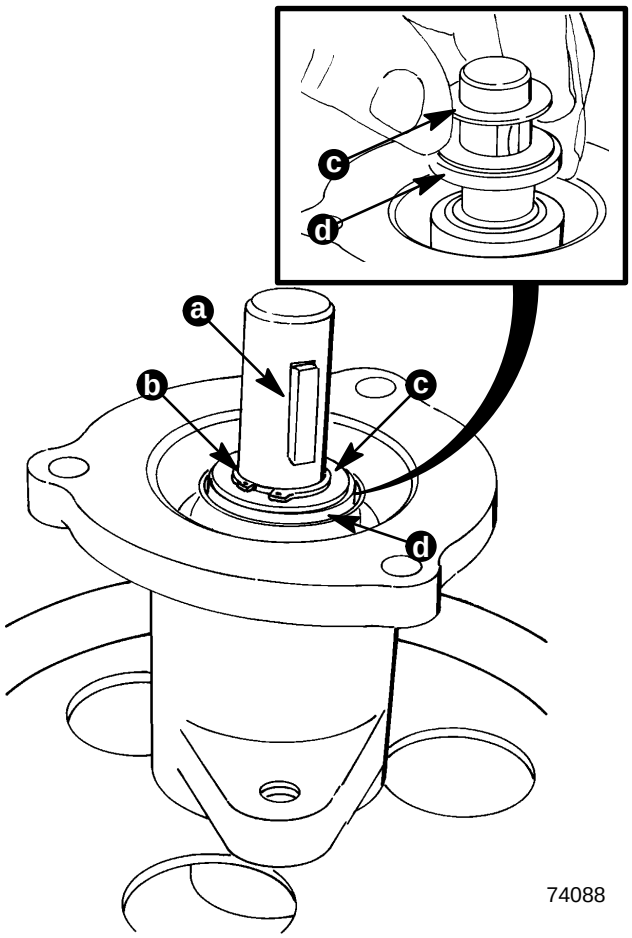
1. Clean metal parts in solvent and blow dry with compressed air.

IMPORTANT: Do not spin bearings at high speed when drying with compressed air, as bearings may be scored.

2. After cleaning, apply a coat of light engine oil to shaft to prevent rust.
3. Clean all gasket material and sealer from sealing surfaces.
4. Inspect cover. Examine surfaces (where bearings contact) for evidence of bearing outer races turning in housing.
5. Inspect seal in cover. Refer to “Seal Replacement” if required.
6. Inspect pump shaft bearings for excessive axial movement or rough rotational feeling (as though it may have pitted bearings).
7. Inspect pump housing.
8. Inspect wear plate.
9. Inspect pump impeller for wear on sides and tips of blades. Also inspect blades for cracks in area where blades flex. Replace impeller if blades have taken a set (remain in curved position).
10. Inspect cam.
11. Inspect pump pulley.
12. Check drive belt for excessive wear.
13. Replace entire pump if any component *which is not provided in the pump repair kit* is found to be defective after the above inspections.

SEAL REPLACEMENT

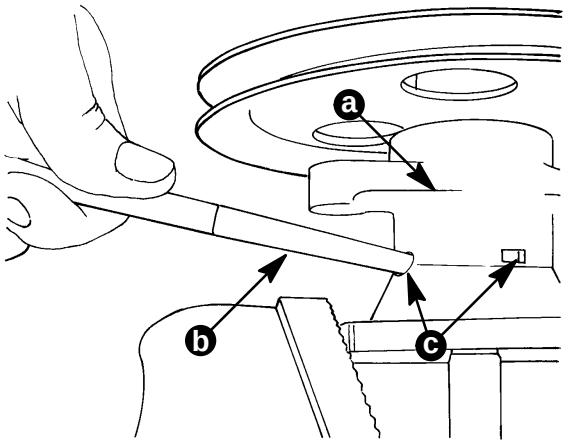
1. Withdraw the impeller woodruff key from its groove.
2. Using suitable snap-ring pliers, remove the external retaining-ring from the shaft groove.
3. Lift off the shoulder washer and the seat assembly (seal) beneath it.



74088

a - Woodruff Key
b - Retaining-Ring
c - Thrust Washer
d - Seal

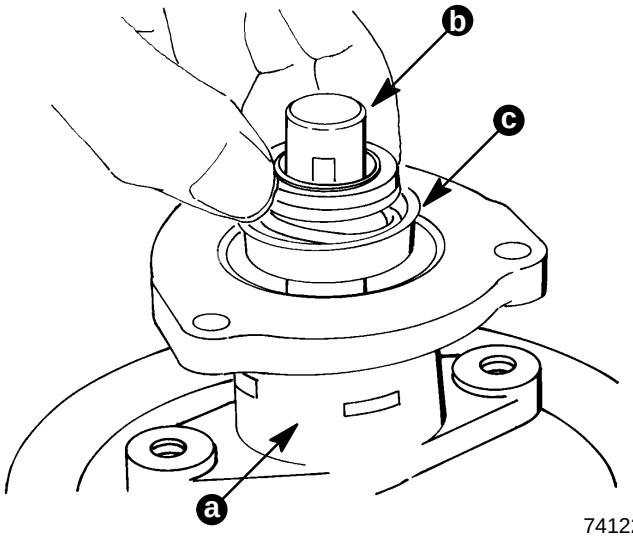
4. Lock the flat sides of the pump cover in a vise. Using a suitable long tappered punch or similar tool, *carefully* pry the mechanical seal out of the cover working through the openings in the cover as shown. Do not damage the bore sealing surface of the cover.



74124

a - Cover
b - Long Tappered Punch (or Similar)
c - Opening(s)

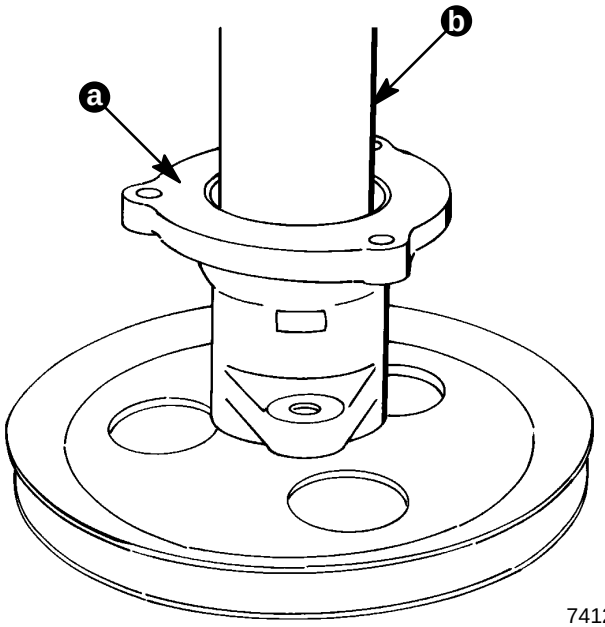
5. Remove the seal from the bore of the cover.
6. Clean the bore of the cover and ensure that no damage was done during removal.
7. Coat the lips of the new mechanical seal with Quicksilver 2-4-C Marine Lubricant or Special Lubricant 101, and place around the shaft as shown.



74122

a - Cover
b - Shaft
c - Mechanical Seal (Metal Backed)

8. Press the mechanical seal into the cover from the impeller end. Make sure the seal is pressed in “square” to the bore. A suitable tool should be used to assure proper assembly.

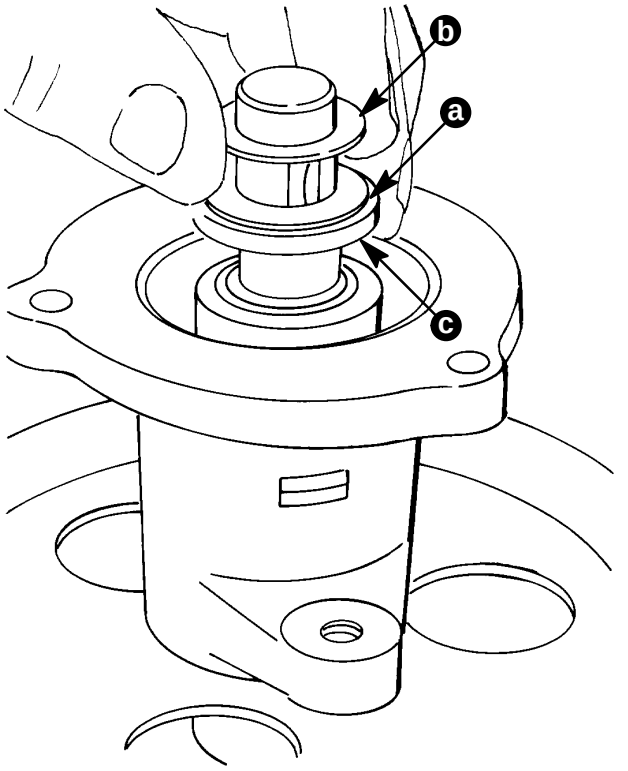


74123

a - Impeller End of Cover
b - Suitable Pressing Tool

9. Coat the lips of the new seat assembly with Quicksilver 2-4-C Marine Lubricant or Special Lubricant 101. Install the new seat assembly and shoulder washer over the shaft as shown. Locate the white ceramic surface against the mechanical seal.

IMPORTANT: Do not damage (scratch) the white ceramic surface of the seat or the seal and seat assembly might leak.

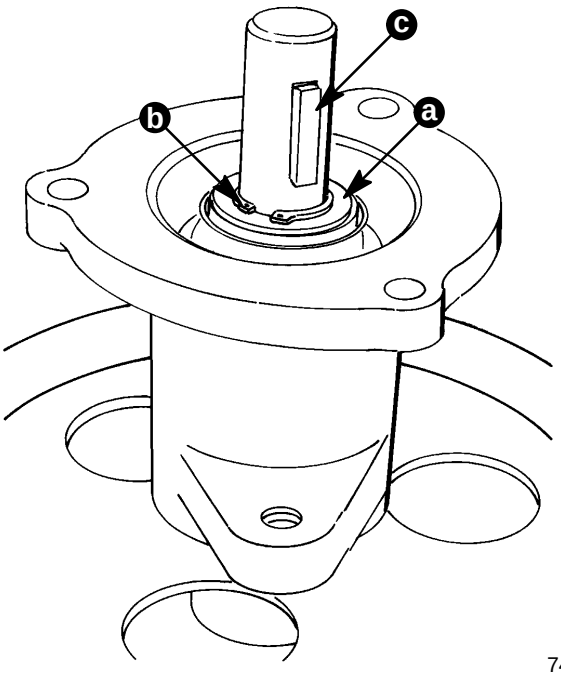


74121

a - Seat Assembly
b - Shoulder Washer
c - White Ceramic Surface (Toward Mechanical Seal)

10. Compress the shoulder washer slighlty onto the seat assembly and install the retaining ring into its groove on the shaft.

11. Press the woodruff key into the shaft. Make sure the brass key is used at this position.



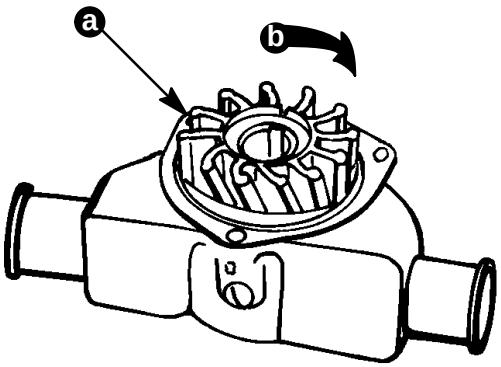
74088

a - Shoulder Washer
b - Retaining Ring
c - Woodfuff Key

REASSEMBLY

Refer to exploded view also.

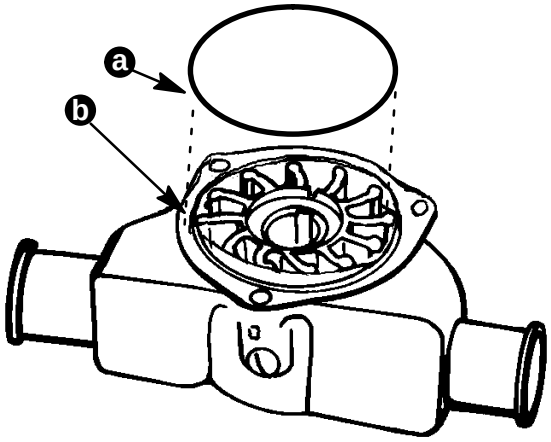
1. Install woodruff key into keyway, making sure key is parallel to shaft.
2. Install impeller into pump body by turning impeller in direction that it will be turning in operation, while simultaneously pushing inward. All impeller blades must face in same direction.



71873

a - Impeller
b - Direction to Turn Into Housing (CLOCKWISE)

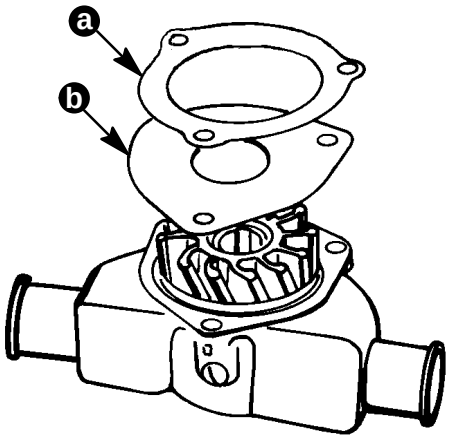
3. Install O-ring seal into groove of pump housing.



71873

a - O-Ring
b - Pump Housing Groove

4. Coat both sides of a new wear plate gasket with a thin film of Quicksilver Perfect Seal. Place gasket on wear plate and align holes. Position both on pump housing.



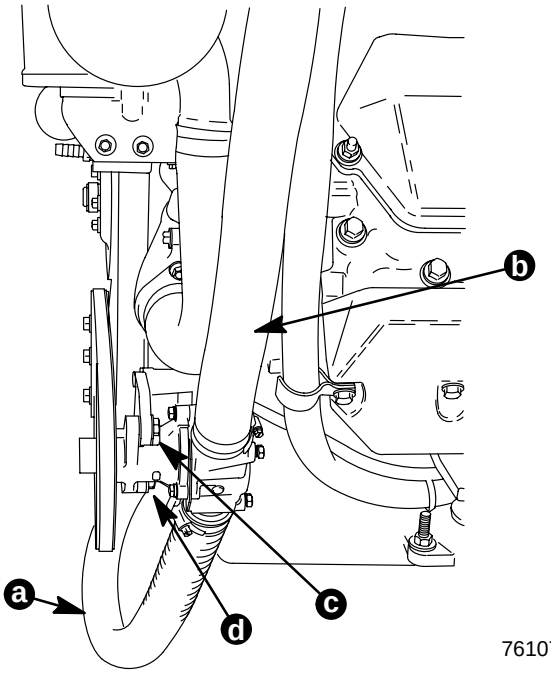
71873

a - Gasket
b - Wear Plate

5. Slide impeller and pump body assembly onto shaft. Position pump housing so that holes align with holes in wear plate, gasket and cover. Torque housing fasteners to 120 lb. in. (14 N•m).

Installation

1. Position pump in mounting bracket.
2. Install the mounting and tensioning bolts. Do not tighten bolts at this time.
3. Position seawater pump drive belt on pulleys and adjust belt tension as outlined in “Drive Belt Tension Adjustment”.
4. Connect seawater inlet hose to lower fitting on pump. Tighten hose clamp securely.
5. Connect outlet hose to upper fitting on pump. Tighten hose clamp securely.



76107

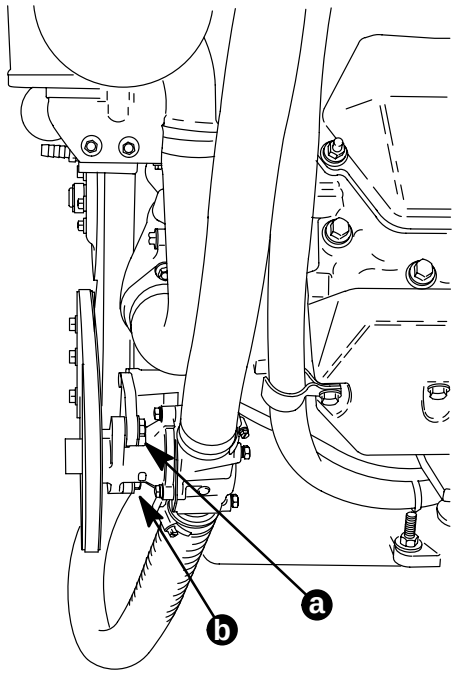
a - Inlet Hose
b - Outlet Hose
c - Mounting Bolt
d - Tensioning Bolt

6. Upon first starting check for leaks and repair as needed.

Drive Belt Tension Adjustment

Seawater Pickup Pump

1. Install drive belt on pulleys and adjust tension as follows:
   a. Pivot pump away from engine. Check drive belt for proper tension by pressing at center point between pulleys. Belt must not deflect more than 1/4 in. (6 mm).
   b. After obtaining correct tension, securely retighten pump tensioning bolt and mounting bolt.



76107

a - Mounting Bolt
b - Tensioning Bolt

2. If a new drive belt has been installed, recheck belt tension after running for five minutes.

Flushing Seawater Cooled Section

If engine is operated in salty, polluted or mineral-laden waters, seawater cooled section should be flushed periodically (preferably after each use) with fresh water to reduce corrosion and prevent the accumulation of deposits in the system. Seawater cooled section also should be thoroughly flushed prior to storage.

NOTE: *The closed section of cooling system that contains coolant does not need to be flushed. Coolant is changed at specified intervals. Refer to "Maintenance Chart."*

⚠ WARNING

When flushing, be certain the area around propeller is clear, and no one is standing nearby. To avoid possible injury, remove propeller.

⚠ CAUTION

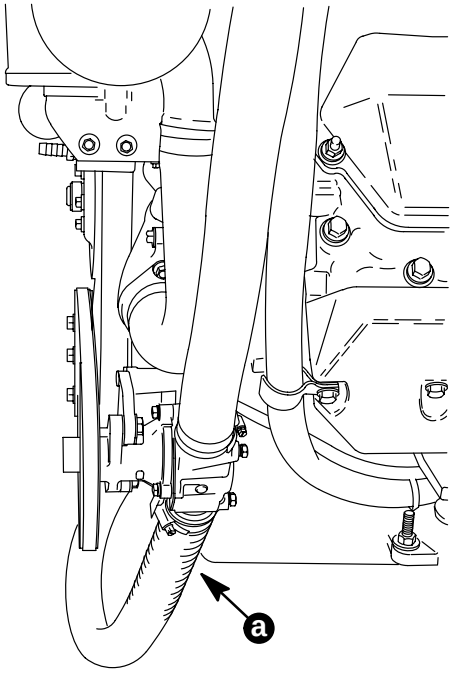
Do not run engine above 1500 RPM when flushing. Suction created by seawater pickup pump may collapse flushing hose, causing engine to overheat.

IMPORTANT: If cooling system is to be flushed with boat in the water, seacock (if so equipped) must be closed, or water inlet hose must be disconnected and plugged to prevent water from flowing into boat.

⚠ CAUTION

Watch temperature gauge at dash to ensure the engine does not overheat.

1. Close seacock (if so equipped) or remove and plug seawater inlet hose.
2. Loosen hose clamp and remove seawater inlet hose at location shown. Connect tap water hose to inlet fitting.



76107

a - Seawater Inlet Hose

3. Place remote control in NEUTRAL, idle speed position and start engine. Operate engine at idle speed, in NEUTRAL, for about 10 minutes, or until discharge water is clear.
4. Stop engine.

⚠CAUTION

If boat is in the water, seacock (if so equipped) must be left closed until engine is to be restarted, to prevent water from flowing back into cooling system. If boat is not fitted with a seacock, water inlet hose must be left disconnected and plugged, to prevent water from flowing into cooling system and/or boat. As a precautionary measure, attach a tag to the ignition switch or steering wheel with the warning that the seacock must be opened or the water inlet hose reconnected prior to starting the engine.

5. Shut off tap water. Remove flushing connector at seawater pump inlet. Refer to preceding precautionary statement and then follow instructions “a” or “b.”
   a. **If equipped with seacock:** Reconnect water inlet hose and tighten hose clamp securely. Open seacock accordingly.
   b. **If NOT equipped with seacock:** Unplug and reconnect seawater inlet hose accordingly. Tighten hose clamp securely.

Check/Clean Seawater Strainer

NOTICE

Refer to manufacturer's instructions for information on checking and cleaning of other than Quicksilver Seawater Strainer.

1. Visually inspect seawater strainer through glass top.

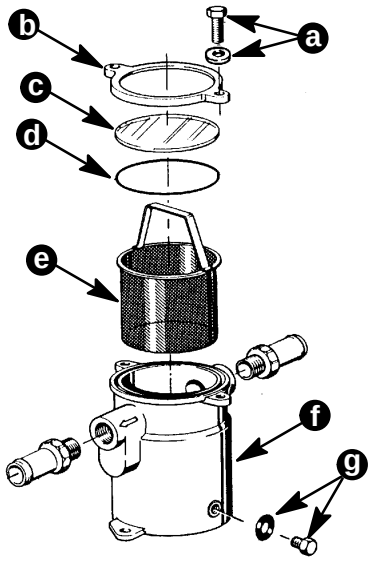
⚠ WARNING

When cleaning seawater strainer, close seacock, if so equipped. If boat is not equipped with a seacock, remove and plug seawater inlet hose to prevent a siphoning action that may occur, allowing seawater to flow from the drain holes or removed hoses.

⚠ CAUTION

Do not over-tighten cover screws or cover will warp and leak.

2. With engine off, close seacock, if so equipped, or remove and plug seawater inlet hose, if no seacock exists. Remove two screws and washers, and cover. Remove strainer, and drain plug and washer. Clean any debris from strainer housing; flush both strainer and housing with clean water. Check gasket; replace when necessary (if it leaks). Reinstall strainer, drain plug and washer. Reattach cover with screws and washers. Open seacock, or unplug and reconnect seawater inlet hose. Tighten hose clamps securely. After starting engine, check for leaks and/or air in system, which would indicate an external leak.



72673

a - Screws and Washers
b - Cover
c - Glass
d - Gasket
e - Strainer
f - Housing
g - Drain Plug and Sealing Washer

Quicksilver Seawater Strainer Shown

Draining Seawater Cooled Section

NOTICE

For cold weather or extended storage information and procedures, refer to Section 1B.

Draining Precautions

⚠CAUTION

If boat is to remain in the water, seacock (water inlet valve), if so equipped, must remain closed until engine is to be restarted to prevent water from flowing back into cooling system and/or boat. If boat is not fitted with a seacock, water inlet hose must be left disconnected and plugged to prevent water from flowing back into cooling system and/or boat. As a precautionary measure, attach a tag to the ignition switch or steering wheel of the boat with the warning that the seacock must be opened or the water inlet hose reconnected prior to starting the engine.

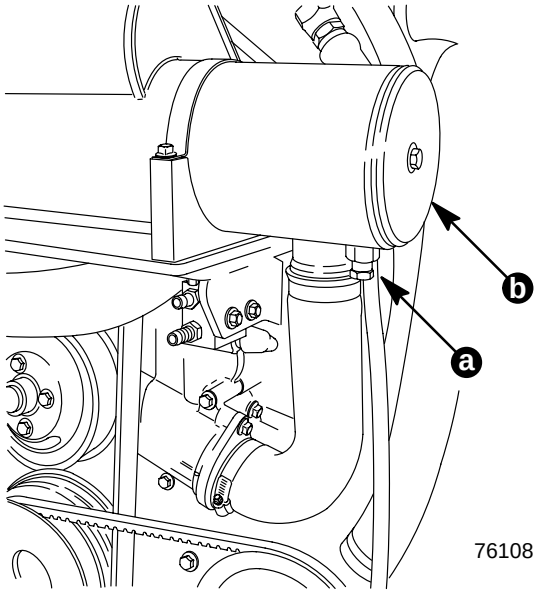
IMPORTANT: Observe the following information to ensure complete draining of cooling system.

- **Engine must be as level as possible.**
- **A wire should be repeatedly inserted into all drain holes to ensure there are no obstructions in passages.**

IMPORTANT: To prevent threads in manifolds, elbows and cylinder blocks from rusting out during storage, reinstall plugs using Quicksilver Perfect Seal on threads. Never leave drain plugs out during storage.

NOTE: *If possible, place a container under drains and hoses to prevent water from draining into boat.*

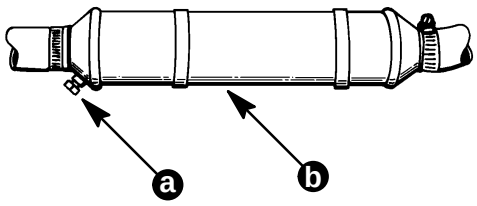
1. Close seacock, if so equipped, or disconnect and plug seawater inlet hose, if boat is to remain in the water.
2. Remove the following drain plugs:
   a. The drain plug located on the bottom of the heat exchanger.



76108

a - Seawater Drain Plug
b - Coolant Tank / Heat Exchanger

   b. The drain plug on the lower side of the engine oil cooler.

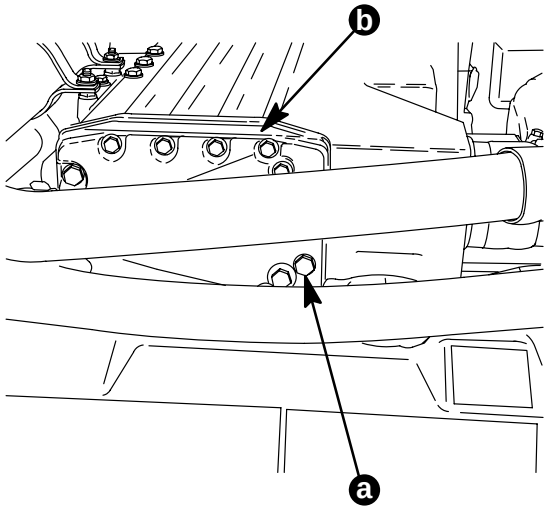


71870

a - Seawater Drain Plug
b - Engine Oil Cooler

c. The aftercooler drain plugs located on the starboard and port aftercooler side covers.

NOTE: *Only the port aftercooler side cover is shown. Starboard is similar.*

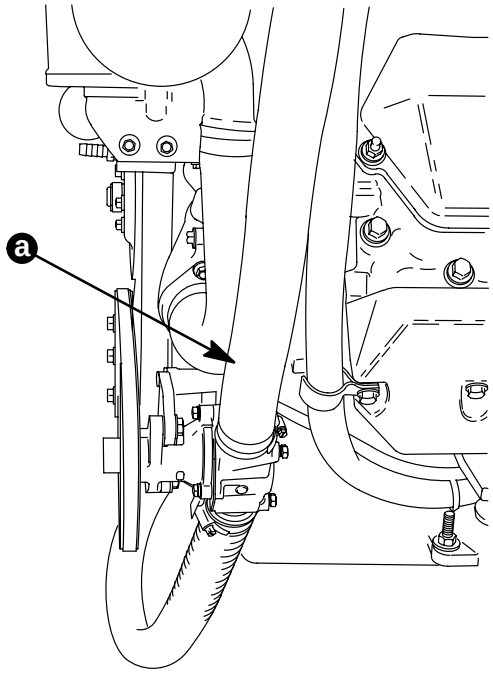


76122

Port Side Shown (Starboard Similar)

a - Aftercooler Drain Plugs
b - Aftercooler Side Cover

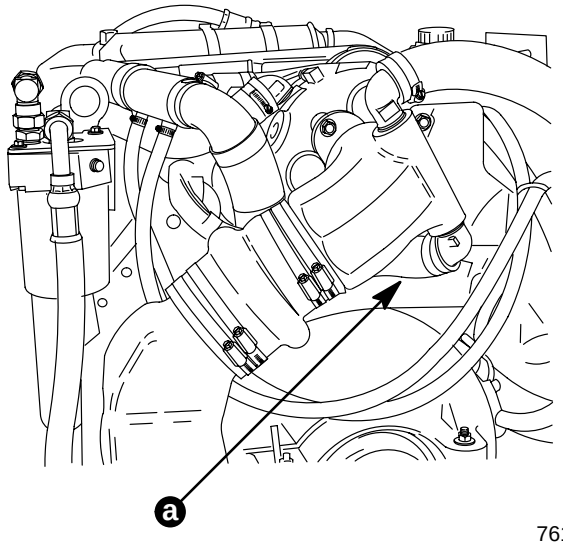
3. Repeatedly clean out drain holes using a stiff piece of wire. Do this until entire system is drained.
4. Remove seawater pump outlet hose from top of seawater pump and drain.



76107

a - Seawater Pump Outlet Hose

5. Disconnect seawater hose at bottom of exhaust elbow. Lower hose and drain completely.



76106

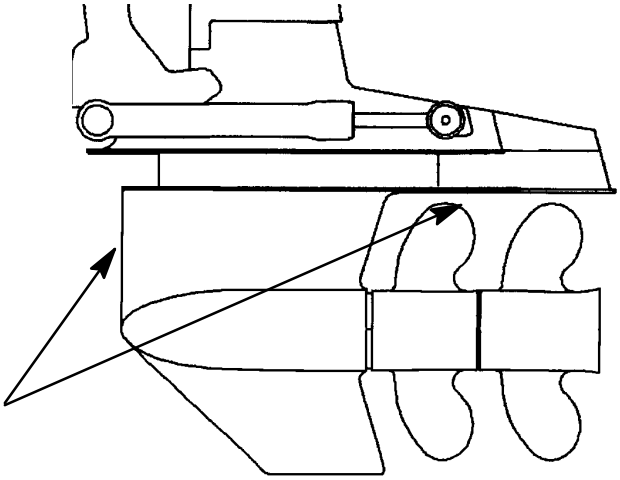
a - Seawater Hose At Exhaust Elbow

⚠CAUTION

Avoid water entering boat. Do not unplug seawater inlet hose unless a seacock is present and it is closed.

6. Remove hose(s) at seawater strainer and drain hose(s) completely. Remove drain plug and empty seawater strainer. Reconnect hoses - tighten hose clamps securely. Install drain plug and tighten securely.

7. Make sure that the drive unit speedometer pitot tube, propeller plate cavity vent hole and drain passages are unobstructed and open. Refer to appropriate Stern Drive Service Manual, as necessary.



71930

8. After seawater section of cooling system has been drained completely, coat threads of drain plugs with Perfect Seal and reinstall. Tighten securely. Connect all hoses previously removed. Tighten hose clamps securely.

Coolant Tank / Heat Exchanger, Oil, Power Steering Fluid Coolers

NOTICE

For information and procedures on the AFTERCOOLER, refer to SECTION 7A.

Cooling efficiency of an engine and components is greatly dependent upon heat transfer through the tubes within the coolers (heat exchangers). During engine operation, contaminants within the seawater (such as salt, silt, lime, etc.) collect on the inside of the tubes, thus reducing heat transfer and greatly decreasing cooler (heat exchanger) efficiency.

It is, therefore, recommended that the seawater coolers be cleaned every 200 hours or at least once a year, or whenever decreased cooling efficiency is suspected.

Additionally, inspect cooler hoses and clamps.

- **For Saltwater Use:** Every 50 hours of operation or 60 days, at least once yearly.
- **For Freshwater Use:** Every 100 hours of operation or 120 days, at least once yearly.

IMPORTANT: If the possibility of freezing exists, seawater section and associated coolers (heat exchangers) MUST be drained to prevent freeze damage to cooling system and engine. Seawater section also should be drained if boat is to be stored for an extended period of time, to prevent corrosion damage.

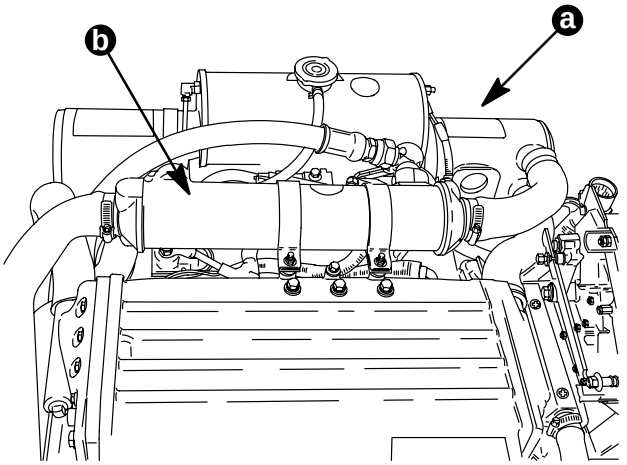
⚠CAUTION

Seawater cooled section MUST be completely drained for storage, or trapped water may cause freeze and/or corrosion damage to engine and/or components.

IMPORTANT: Closed cooling section of cooling system must be kept filled year-round with the specified coolant.

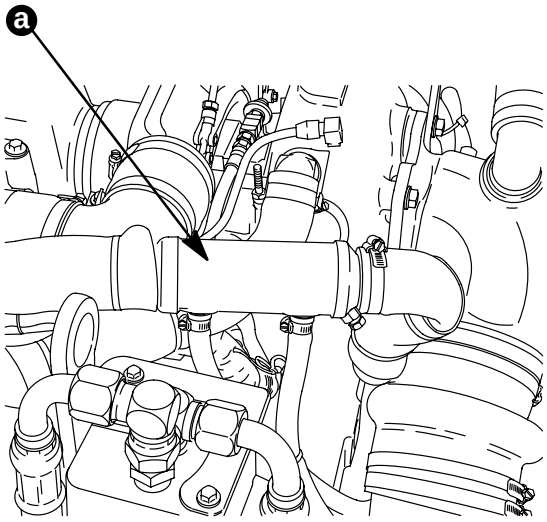
Location of Coolers

Refer to the following for location of coolant tank/heat exchanger, oil, and power steering coolers.



76123

a - Coolant Tank/Heat Exchanger
b - Engine Oil Cooler



76121

a - Power Steering Fluid Cooler

Inspection

1. Refer to “Draining Seawater Cooled Section” and drain the seawater section.
2. Refer to the appropriate instructions following for inspection of cooler(s).
   a. **Oil, Power Steering Fluid Coolers:** Loosen hose clamp and disconnect hose from INLET end (refer to “Water Flow Diagram”) of the appropriate cooler(s) and inspect passages.
   b. **Coolant Tank/Heat Exchanger:** Remove end cap from INLET end (refer to “Water Flow Diagram”) of the appropriate cooler(s) and inspect passages.
3. If passages appear blocked or restricted with contaminants, cleaning is required. Refer to the following section.
4. If blockage or restriction *is not* present, refer to the appropriate reassembly instructions following.
   a. **Oil, Power Steering Fluid Coolers:** Reconnect hose to inlet end of cooler and secure using hose clamp. Tighten hose clamp securely.
   b. **Coolant Tank/Heat Exchanger:** Clean mating surfaces of debris. Install end cap to inlet end of cooler using fastener. Torque fastener to 72 lb. in. (8 N·m).

Cleaning

1. Refer to “Draining Seawater Cooled Section” and drain the seawater section, if not already accomplished.
2. Remove hoses from both ends of cooler (heat exchanger) to be cleaned.
3. Temporarily attach a suitable hose to **inlet** end of cooler and place end of hose in a suitable container to catch water in the following.
4. Attach a suitable adaptor to the **outlet** end of cooler to which a tap water hose may be connected.
5. Open tap water faucet and “backflush” cooler until discharge water is clean.
6. Remove temporary hose and adaptor from cooler. Remove BOTH end caps from coolant tank/heat exchanger.
7. **If passages are clear,** refer to the appropriate reassembly instructions following:

a. **Oil, Power Steering Fluid Coolers:** Reconnect seawater hoses to cooler. Tighten hose clamps securely.

b. **Heat Exchanger:** Clean mating surfaces of debris. Install end caps to cooler using fasteners. Torque fasteners to 72 lb. in. (8 N·m).

IMPORTANT: MerCruiser does not recommend the immersion of coolers or heat exchangers in cleaning solutions. If backflushing of the problem cooler does not satisfactorily clear the passages, replacement of the cooler or heat exchanger is recommended.

If passages are still obstructed, refer to the appropriate instructions following:

c. **Oil, Power Steering Fluid Coolers:** It will be necessary to replace the cooler. Refer to the following section.

d. **Coolant Tank/Heat Exchanger:** Clean water passages by inserting a suitable size wire brush into each passage. Use compressed air to blow loose particles out of water passages. Refer to “a” and “b” as follows for reassembly instructions.

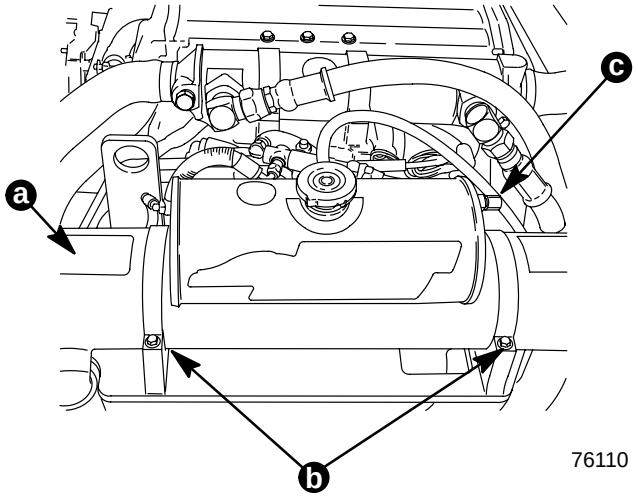
(1) **Oil, Power Steering Fluid Coolers:** Reconnect hose to inlet end of cooler and secure using hose clamp. Tighten hose clamp securely.

(2) **Coolant Tank/Heat Exchanger:** Clean mating surfaces of debris. Install end cap to inlet end of cooler using fastener. Torque fastener to 72 lb. in. (8 N·m).

Removal

COOLANT TANK/HEAT EXCHANGER

1. Refer to “Draining Seawater Cooled Section” and drain the seawater section, if not already accomplished.
2. Refer to “Changing Coolant - Draining Instructions” in SECTION 6B and drain the closed cooled section.
3. Disconnect all hoses from heat exchanger.
4. Disconnect turbocharger vent pipe from fitting at heat exchanger.
5. Remove four heat exchanger mounting fasteners and remove heat exchanger.



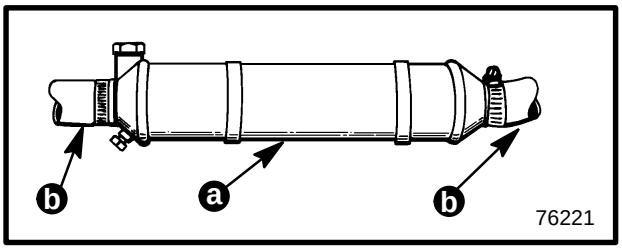
a - Coolant Tank/Heat Exchanger
b - Mounting Fasteners and Hardware (4 Places)
c - Turbo Vent Pipe and Fitting

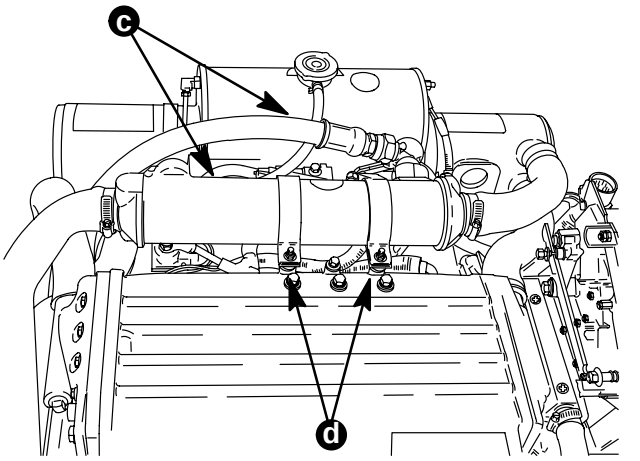
ENGINE OIL COOLER

1. Refer to “Draining Seawater Cooled Section” and drain the seawater section, if not already accomplished.
2. Disconnect seawater hoses from both ends of cooler.

IMPORTANT: Obtain clean, suitable devices to plug oil lines, to avoid loss of engine oil, in the following step.

3. Disconnect oil lines from cooler one at a time. Quickly plug lines to avoid loss of engine oil. Use a separate wrench to stabilize the cooler fittings while loosening oil lines.
4. Remove oil cooler mounting clamp nuts. Remove oil cooler. Drain oil from oil cooler into a suitable container.





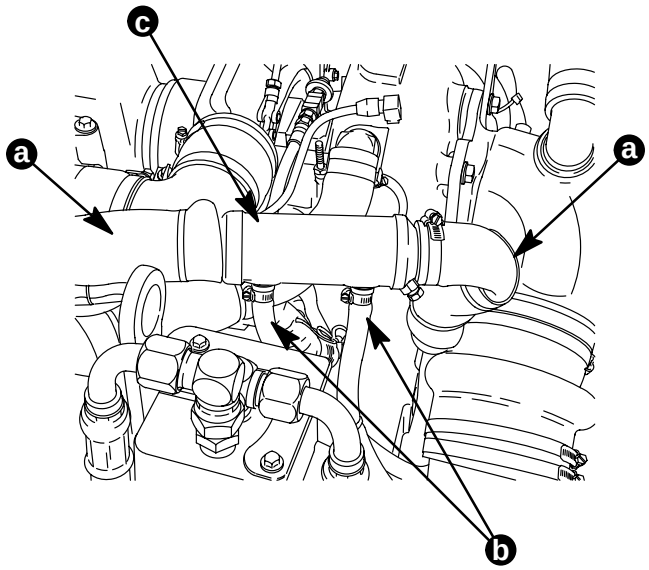
a - Engine Oil Cooler
b - Seawater Hoses
c - Oil Lines and Fittings
d - Mounting Clamp Nuts

POWER STEERING FLUID COOLER

1. Refer to “Draining Seawater Cooled Section” and drain the seawater section, if not already accomplished.
2. Disconnect seawater hoses from both ends of cooler.

IMPORTANT: Obtain clean, suitable devices to plug power steering lines, to avoid loss of power steering fluid, in the following step.

3. Disconnect power steering lines from cooler one at a time. Quickly plug lines to avoid loss of power steering fluid.
4. Remove cooler mounting clamp and remove cooler. Drain fluid from cooler into a suitable container.



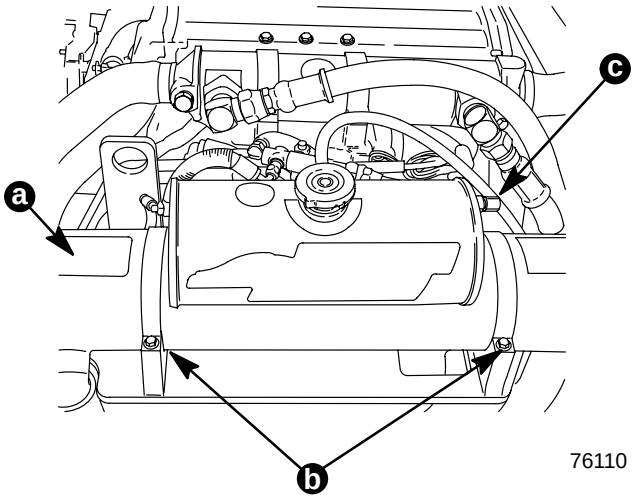
a - Seawater Hoses
b - Fluid Lines
c - Power Steering Fluid Cooler

Installation

COOLANT TANK/HEAT EXCHANGER

NOTE: *If not already accomplished, remove sacrificial anode from port fitting in tank. Replace if more than 50% deteriorated. Refer to SECTION 1B, "Anodes".*

1. Install drain plug (sacrificial anode) in tank, if not already fitted. Tighten securely.
2. Install heat exchanger to mounting brackets using fasteners and hardware. Be certain pressure cap is upright and horizontal. Torque fasteners to 30 ft. lb. (41 N·m).
3. Reconnect all hoses to coolant tank/heat exchanger and tighten each hose clamp securely.
4. Connect turbocharger vent line at fitting on tank. Tighten securely.



76110

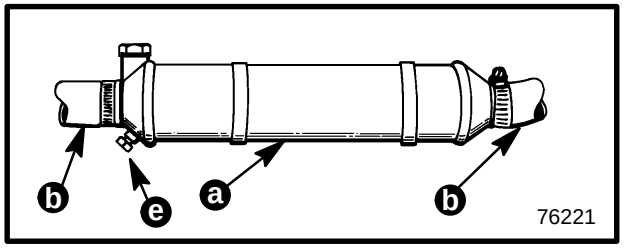
a - Coolant Tank/Heat Exchanger
b - Mounting Fasteners and Hardware (4 Places)
c - Turbocharger Vent Pipe and Fitting

5. Refer to "Filling Closed Cooled Section" in Section 6B and fill the closed coolant system with specified coolant mixture.

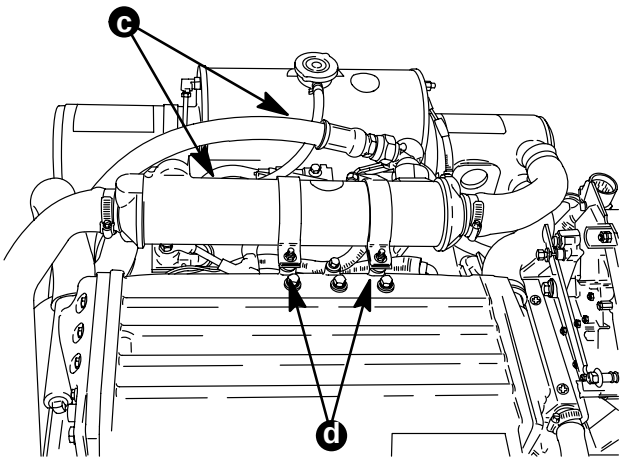
ENGINE OIL COOLER

NOTE: *If not already accomplished, remove sacrificial anode from fitting in cooler. Replace if more than 50% deteriorated. Refer to SECTION 1B, "Anodes".*

1. Install sacrificial anode in cooler, if not already fitted. Tighten securely.
2. Install oil cooler to engine using mounting clamps and nuts. Tighten mounting clamp nuts securely.
3. Unplug oil lines one at a time. Quickly reconnect lines to oil cooler to avoid loss of engine oil. Use a separate wrench to stabilize the cooler fittings while tightening oil lines.
4. Reconnect seawater hoses to oil cooler and secure using hose clamps. Tighten hose clamps securely.



76221

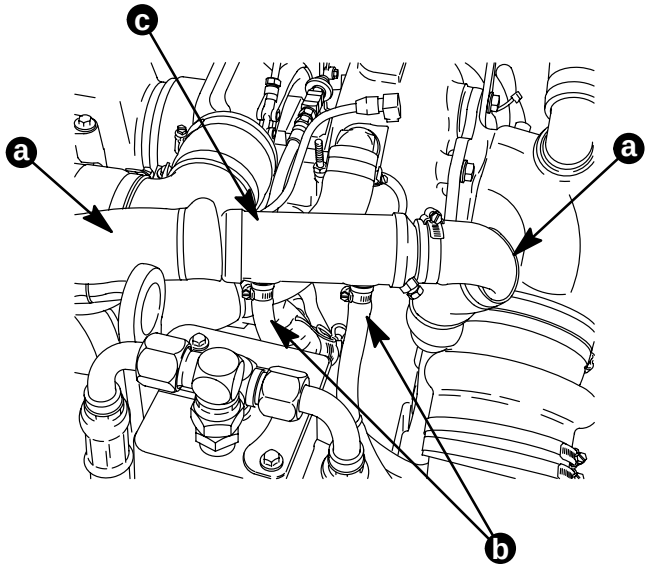


76123

a - Engine Oil Cooler
b - Seawater Hoses
c - Oil Lines and Fittings
d - Mounting Bracket Nuts
e - Drain Plug (Sacrificial Anode)

POWER STEERING FLUID COOLER

1. Unplug power steering lines one at a time. Quickly reconnect lines to cooler to avoid loss of power steering fluid. Tighten hose clamps securely.
2. Reconnect seawater hoses to cooler and secure using hose clamps. Tighten hose clamps securely.



76121

a - Seawater Hoses
b - Fluid Lines
c - Power Steering Fluid Cooler

Exhaust Elbow

Removal

1. Refer to SECTION 7C -“Removing Exhaust Elbow.
2. Remove exhaust elbow accordingly.

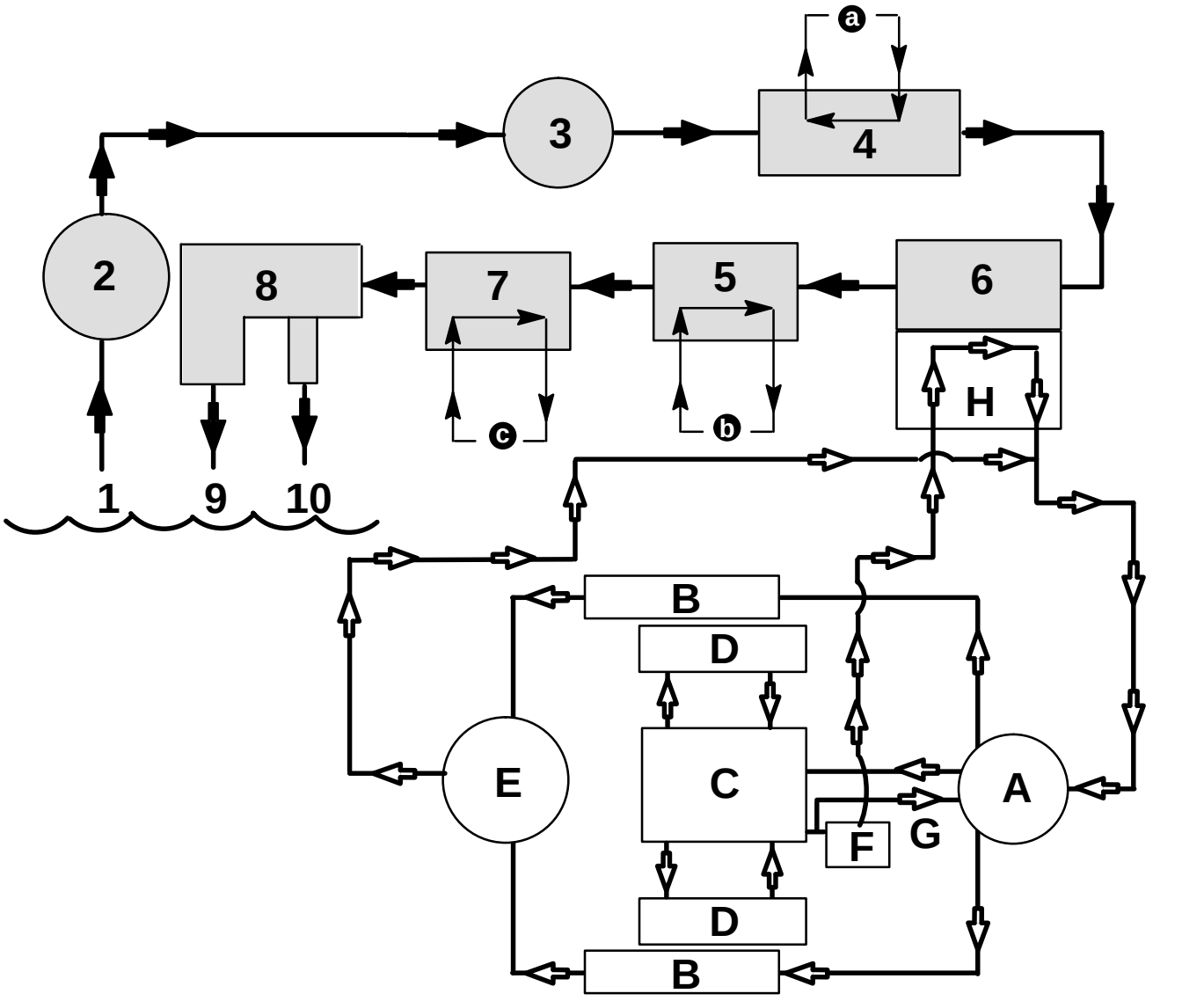
Cleaning

Using a hose connected to a tap water faucet,and with exhaust elbow removed, spray seawater opening at exhaust hose end of elbow to achieve a “backflush” effect. Backflush water through exhaust elbow until discharge water is clean.

Installation

1. Refer to SECTION 7C -“Installing Exhaust Elbow.
2. Install exhaust elbow accordingly.

Water Flow Diagram



SEAWATER COOLING CIRCUIT (RAW WATER)

1 - Seawater Inlet (Thru Drive)
2 - Seawater Strainer
3 - Seawater Pump
4 - Aftercooler
5 - Engine Oil Cooler
6 - Heat Exchanger (Seawater Circuit)
7 - Power Steering Fluid Cooler
8 - Exhaust Pipe Water Jacket
9 - Seawater Outlet (Exhaust Pipe)
10- Seawater Outlet (Overboard Discharge Fitting)

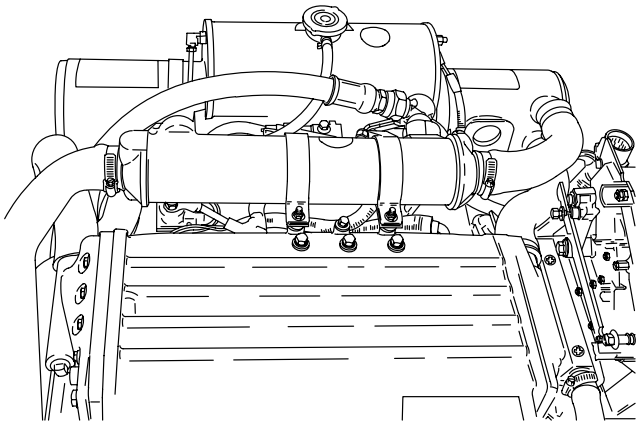
CLOSED COOLING CIRCUIT (FRESH WATER/COOLANT)

A - Circulating Pump - Closed Coolant
B - Exhaust Manifolds
C - Engine Crankcase
D - Cylinder Heads
E - Turbocharger
F - Thermostat
G - Bypass
H - Heat Exchanger (Closed Cooling Circuit)

FLOW OF :

ⓐ ENGINE AIR
ⓑ ENGINE OIL
ⓒ POWER STEERING FLUID

COOLING SYSTEM



76123

6

B

CLOSED COOLED SECTION

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Water Flow Diagram	6B-20

Torque Specifications

Fastener Location	Lb. Ft. (N•m)	Lb. In. (N•m)
Alternator Brace to Alternator		192 (28)
Alternator Brace to Heat Exchanger Mounting Bracket	30 (41)	
Alternator Mounting Bracket	30 (41)	
Alternator to Mounting Bracket	35 (48)	
Drain Plugs (Note)	Securely	
Heat Exchanger End Cap		72 (8)
Heat Exchanger to Bracket	30 (41)	
Hose Clamps	Securely	
Power Steering Pump Brace	30 (41)	
Power Steering Pump Bracket	30 (41)	
Pulley	Securely	
Seawater Pump Bracket to Block	30 (41)	
Seawater Pump to Bracket	35 (48)	
Thermostat Housing	20 (27)	
Water Circulating Pump	14 (19)	168 (19)

NOTE: *Coat threads with Quicksilver Perfect Seal before installing.*

Lubricants/Sealants

Item/Description	Part Number
Special Lubricant 101	92-13872A1
Quicksilver Perfect Seal	92-34227-1
Loctite Master Gasket	92-12564-1
Gasket Sealer	92-72592-1
Loctite Pipe Sealant with Teflon	Obtain Locally
Permatex Aviation Sealer - No. 3	Obtain Locally

Cooling System Cleaners

Item/Description	Part Number
Quicksilver Cooling System Cleaner	91-814825
Fleetguard Restore	CC2610 -Obtain Locally

Special Tools

Item/Description	Part Number
Pink Litmus Paper	Obtain Locally
Thermostat Tester	Obtain Locally
Heat Exchanger Cleaning Brush Can be obtained from: Schaefer Brush Manufacturing Company 117 West Walker Street Milwaukee, WI 53204 U.S.A.	01299

Specifications

Closed Cooled Section Capacity

Engine	U.S. Qts. (L) Approximate
All Engines	26 (24.5)

Thermostat

Engine	Specification
All Engines	170°F (77°C)

Pressure Cap Rating

Engine	Specification
All Engines	14 PSI (97 kPa) [1]

[1] : Must hold rated pressure for 30 seconds without going below 11 psi (76 kPa).

Coolant

Refer to “Coolant for Closed Cooling System” in SECTION 1B for coolant specifications.

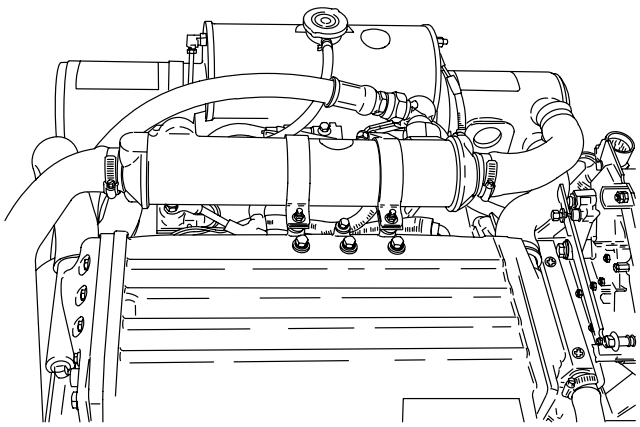
Description

The cooling system is composed of two separate sections: the seawater section and the closed cooled section. The seawater section is similar in function to the fan used in an automobile because it absorbs heat (from the closed cooled section) as it passes through the heat exchanger. The closed cooled section is similar in function to the rest of the cooling system in an automobile.

The coolant recovery system keeps the reservoir full. Normal coolant overflow into recovery bottle is approximately 1/2 pint (230 mL) during warm-up. The coolant recovery system draws coolant back into the reservoir from the recovery bottle as the engine cools. As long as there is coolant in the recovery bottle, the reservoir should remain completely full. If not, there’s a vacuum leak, usually at the hose leaving the reservoir, or the gasket under the filler cap. The gasket seals against the outer rim of the filler neck.

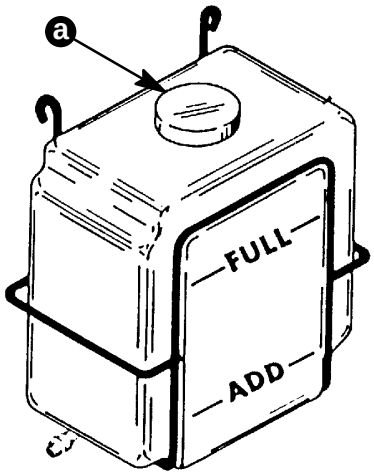
IMPORTANT: The coolant (antifreeze) flows around the outside of the cooling tubes while seawater flows through the inside of the cooling tubes in the heat exchanger.

All V-8 engine exhaust manifolds are cooled by coolant in the closed cooled section. All engines use a belt driven pump to pump seawater through the coolant tank/heat exchanger.



76123

Maintaining Coolant Level



72520

a - Fill Cap

Coolant Recovery Bottle

Before starting engine each day, check to ensure that coolant is visible in coolant recovery bottle.

If coolant is not visible, check fresh water section of cooling system (including coolant recovery system) for leaks and repair, as necessary. Refill fresh water section with recommended coolant solution, as outlined under “Changing Coolant,” following.

If coolant is visible, start engine and run until it reaches normal operating temperature, then recheck coolant level in coolant recovery bottle. Coolant level MUST BE between the ADD and FULL marks (on front of bottle).

⚠WARNING

Allow engine to cool before removing pressure cap, as sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

If level is low, remove fill cap from coolant recovery bottle and add required amount of coolant solution. Use only specified Quicksilver Premixed Marine Engine Coolant for coolant additions. If frequent additions of coolant are required, check fresh water section for leaks.

IMPORTANT: ALCOHOL OR METHANOL BASE ANTIFREEZE OR PLAIN WATER ARE NOT RECOMMENDED FOR USE IN COOLING SYSTEM AT ANY TIME.

Occasionally, check to ensure that coolant recovery system is functioning properly by removing pressure cap from heat exchanger and checking level. Coolant level should be up to bottom of heat exchanger filler neck. If low, examine entire fresh water section (especially coolant recovery system) for leaks and repair, if necessary.

IMPORTANT: When reinstalling pressure cap, be sure to tighten it until it contacts stops on filler neck.

Pressure Cap Maintenance

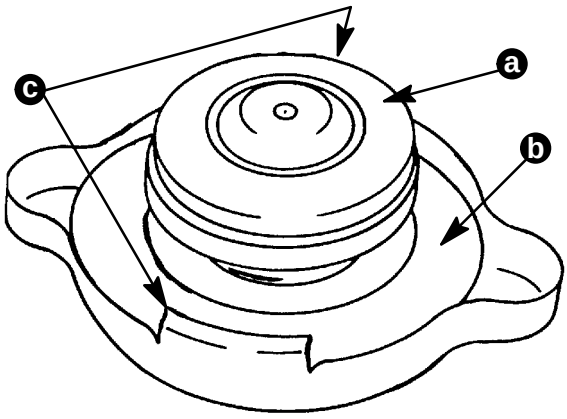
Pressure cap is designed to maintain pressure in fresh water section of the cooling system once the engine has attained normal operating temperature. This raises the boiling point of the coolant, thereby increasing the efficiency of the cooling system. To help ensure proper operation, cap should be cleaned, inspected and pressure tested periodically as follows:

⚠WARNING

Allow engine to cool before removing pressure cap (in next step), as sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

1. Remove pressure cap from heat exchanger.
2. Wash cap with clean water to remove any deposits or debris from sealing surfaces.
3. Inspect rubber seal on cap for cuts, cracks or other signs of deterioration. If seal is damaged, cap MUST BE replaced.
4. Inspect coolant recovery gasket for deterioration and replace if bad.

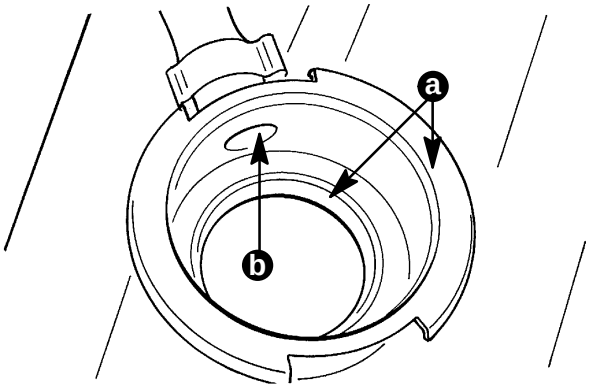
5. Check condition of locking tabs on cap. Replace cap if tabs are bent or cracked.



72714

a - Rubber Seal (Cap MUST BE Replaced if Damaged)
b - Gasket (Look for Cracks under Gasket)
c - Locking Tabs (1 Hidden)

6. Refer to “Testing Pressure Cap” and test pressure cap as outlined.
7. Clean sealing surfaces on heat exchanger filler neck with a cloth. Inspect surfaces for any damage or deposits that may prevent cap from sealing properly.
8. Clean coolant recovery passage in heat exchanger filler neck with a wire and blow out with compressed air.



72715

a - Inspect for Damage
b - Clean Coolant Recovery Passage

9. Reinstall pressure cap, being sure to tighten until it contacts stops on filler neck.

Heat Exchanger Repair

IMPORTANT: Braze with BCUP 2 rod or silver solder. Care must be taken not to melt other joints during repair.

1. Internal leaks can be repaired by brazing shut the ends of the leaking tube. This is only a temporary fix because usually another tube will start leaking after a short period of time and this also causes a reduction in cooling capacity. Do not close more than three tubes.
2. Nipples and drains that have been broken off the heat exchanger can be reattached by brazing.

Testing Closed Cooled Section

Testing Coolant for Alkalinity

⚠WARNING

Allow engine to cool before removing pressure cap as sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

Coolant in fresh water section should be changed every two years and should be checked for alkalinity at least once between change intervals. To check coolant for alkalinity, proceed as follows:

1. Obtain pink litmus paper from a local supplier (drug store, pet shop, etc.).
2. Remove pressure cap from heat exchanger and insert one end of litmus paper into coolant.
3. **If pink litmus paper turns blue,** coolant is alkaline and need not be replaced.
4. **If pink litmus paper remains pink,** coolant is not alkaline and MUST BE REPLACED, as explained under “Changing Coolant”.

Pressure Testing System

⚠ WARNING

Allow engine to cool before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

If coolant section of closed cooled section is suspected of leaking or not holding sufficient pressure, and no visible signs of leakage can be found, perform the following test:

1. Remove pressure cap from heat exchanger or reservoir.
2. Clean, inspect and pressure test pressure cap, as outlined under “Testing Pressure Cap,” to eliminate the possibility that cap is not maintaining proper pressure in system and is causing coolant to boil over.
3. Clean inside of filler neck to remove any deposits or debris. Examine lower inside sealing surface for nicks or other damage. Surface must be perfectly smooth to achieve a good seal between it and rubber seal on cap. Also check locking cams on sides of filler neck to be sure that they are not bent or damaged. If locking cams are bent or damaged, pressure cap will not hold the proper pressure.
4. Adjust coolant level in fresh water section to 1 in. (25 mm) below filler neck.
5. Attach an automotive-type cooling system pressure tester to filler neck and pressurize closed cooled section to amount specified in following chart, based on pressure cap rating for your engine.

Pressure Cap Rating	Amount of Pressure Applied to Closed Cooled Section
14 PSI (97 kPa)	20 PSI (137 kPa)

6. Observe gauge reading for approximately two minutes; pressure should not drop during this time. If pressure drops, proceed with the following steps until leakage is found.
7. While maintaining specified pressure on closed cooled section, visually inspect external portion of cooling system (hoses, gaskets, drain plugs, core plugs, circulating pump seal, etc.) for leakage. Also listen closely for bubbling or hissing, as they usually are a sure indication of a leak.
8. Refer to “Testing Heat Exchanger” in this section and test as outlined.
9. If no leakage could be found in above steps, engine is leaking internally, and it probably is due to one or more of the following: (1) loose cylinder head bolts or damaged gasket, (2) loose turbocharger bolts or damaged gasket, (3) loose exhaust elbow or damaged gasket, (4) cracked or porous cylinder head or block, or (5) cracked or porous exhaust manifold. Proceed as follows until location of internal leak is found.
   a. Start engine. Pressurize system to previously specified amount and observe pressure gauge on tester. If needle in gauge vibrates, compression or combustion is leaking into closed cooled section from a leak in the combustion chamber. Stop engine.
   b. Remove glow plugs (one at a time) from cylinders and examine for presence of coolant. A glow plug that is perfectly clean or milky appearing is a sure indication of a leak.
   c. Drain oil from engine and examine for presence of coolant. Oil usually will be milky if coolant is present. If coolant is present, remove engine from boat and remove the oil pan. With engine in the upright position, pressurize closed cooled section to previously specified amount and examine internal surfaces of engine to locate leak.
   d. If no leakage can be found in above steps, entire engine must be disassembled and inspected for leakage.

Testing for Cylinder Head Gasket Leak

A leaking head gasket will cause combustion gas to be forced into the cooling system. The mixture of coolant and tiny air bubbles is a poor heat conductor and will overheat an engine quickly. Compression tests or cooling system pressure check normally will not detect the leak because the test pressure is far below the combustion pressures which cause the leak. An effective test is as follows:

IMPORTANT: Run boat in lake for this test. It is best to run the engine at or above cruising speed during this test. Usually a failed head gasket will not cause the engine to overheat below cruising speed.

1. Install a clear plastic hose between the reservoir and coolant recovery bottle. Use a 2-3 ft. (61-91 cm) long hose for this test.
2. Route this hose so a “U” is formed.
3. Put enough coolant into hose to fill the center 4 or 5 inches (10-13 cm) of the “U”.
4. Observe the “U” while the engine is running.
    a. **During Idle and Warm-Up:** Some coolant and/or air will leave the reservoir.
    b. **During Cruising Speed (2500-3000 RPM):** Coolant and/or air leaving the reservoir should stop after approximately five minutes running at a given RPM. A leaking head gasket will produce air bubbling through the “U,” going to the coolant recovery bottle. The frequency and size of the bubbles will depend on the size of the leak.
    c. **At Higher Speeds (3000 - 3400 RPM):** Normal operation is the same as described in “b” above. A failed head gasket will cause the bubbles to come faster and may be accompanied by violent, intermittent bursts of coolant.

It is important not to confuse normal warm-up expansion with a failed head gasket. Normal warm-up produces an intermittent flow of coolant which will stop within approximately five minutes at a given RPM. A head gasket leak will not stop because the one thing that marks a failed head gasket is the continued passage of air. This may be accompanied by violent, intermittent bursts of coolant leaving the reservoir. If coolant continues to flow (not in violent, intermittent bursts) from the reservoir at cruising speed, something other than the head gasket is causing the engine to overheat.

Testing Heat Exchanger

FOR INTERNAL LEAK: An internal leak will cause coolant to go into the seawater circuit when pressure is put on the closed cooling circuit.

1. Remove top seawater (inlet) hose from the exchanger. Do not drain the exchanger.
2. Pressurize the closed cooling circuit to 14 PSI (97 kPa) with a radiator tester.
3. If seawater begins to flow from the nipple there is a leak.

FOR INTERNAL BLOCKAGE:

IMPORTANT: Seawater flows THROUGH the tubes in the exchanger. Closed cooling coolant flows AROUND the tubes.

1. Remove end caps and inspect for any blockage in the seawater circuit (weeds, etc.).
2. Remove closed cooling circuit hoses and inspect the tubes just inside the nipples. Because the complete exchanger cannot be inspected, the heat exchanger should be replaced if blockage is suspected.

Testing Pressure Cap

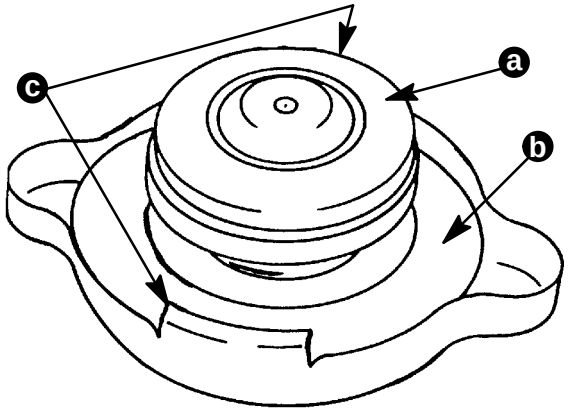
Pressure cap is designed to maintain a pressure of approximately its rated capacity (refer to “Specifications”) in closed cooled section once engine has attained operating temperature. Cap should be cleaned, inspected and pressure-tested at regular tune-up intervals or whenever cap is suspected of maintaining improper pressure as follows:

⚠WARNING

Allow engine to cool before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

1. Carefully remove pressure cap from reservoir or heat exchanger.
2. Wash cap with clean water to remove any deposits or debris from sealing surfaces.

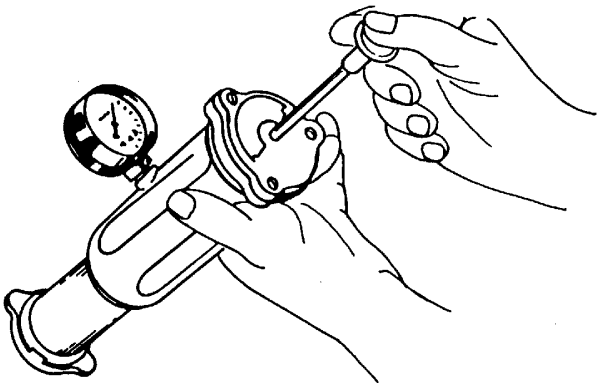
3. Inspect gasket (if used) and rubber seal on cap for tears, cuts, cracks or other signs of deterioration. Replace gasket, if damaged, or entire cap if rubber seal is damaged.



72714

a - Rubber Seal (Cap MUST BE Replaced if Damaged)
b - Gasket (Look for Cracks under Gasket)
c - Locking Tabs (1 Hidden)

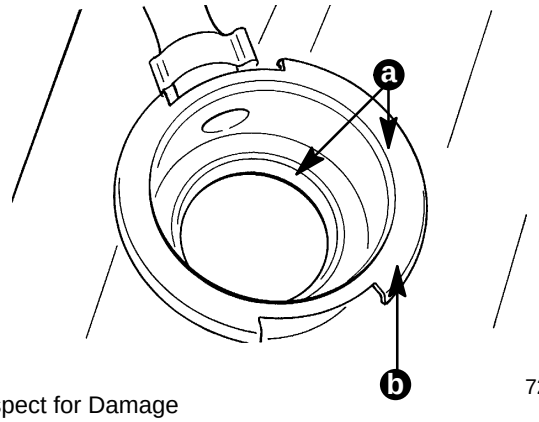
4. Check that locking tabs on cap are not bent or damaged.
5. Using a cooling system pressure tester (similar to one shown), test cap to be sure that it releases at proper pressure and does not leak. (Refer to instructions which accompany tester for correct test procedure.) Cap must relieve pressure at 14 PSI (97 kPa), and must hold rated pressure for 30 seconds without going below 11 PSI (76 kPa). Replace cap if it fails to operate within these limits.



72716

Typical Cooling System Pressure Tester

IMPORTANT: Before reinstalling cap in next step, examine lower inside sealing surface in filler neck to ensure that it is perfectly smooth and free of debris. Also, inspect cam lock flanges on sides of filler neck to be sure that they are not bent.



72715

a - Inspect for Damage
b - Cam Lock Flange

6. Reinstall cap on reservoir or heat exchanger.

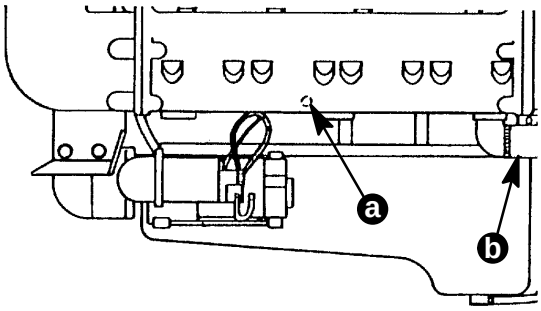
Thermostat

Removal

1. Follow instructions “a” and “b”:
   a. Drain coolant from exhaust manifolds by removing lower hose from each manifold. Be sure to drain both port and starboard sides.

NOTE: *If coolant flow is restricted or fails to occur, a wire should be repeatedly inserted into all drain holes to ensure there are no obstructions in passages.*

   b. Drain engine block by removing drain plugs. Be sure to drain both port and starboard sides.



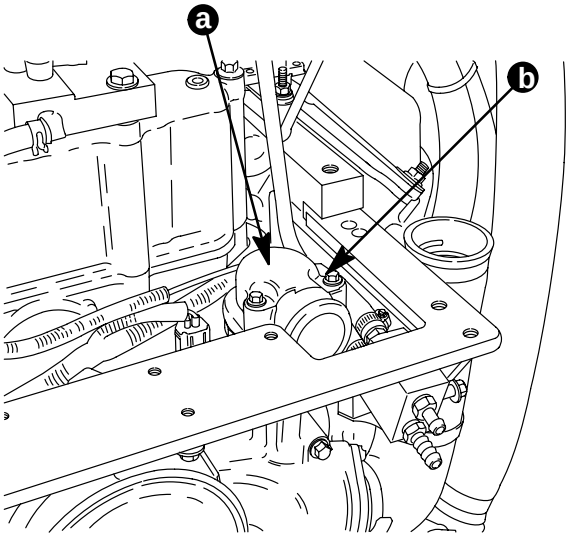
73255

a - Drain Plug on Cylinder Block
b - Hose

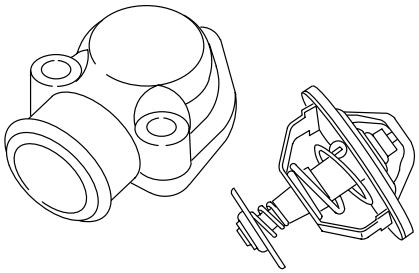
Port Side Shown (Starboard Side Similar)

2. Disconnect hose from thermostat housing.

3. Remove thermostat housing attaching bolts and lockwashers, then remove housing and gasket.
4. Remove thermostat from engine block.



76141

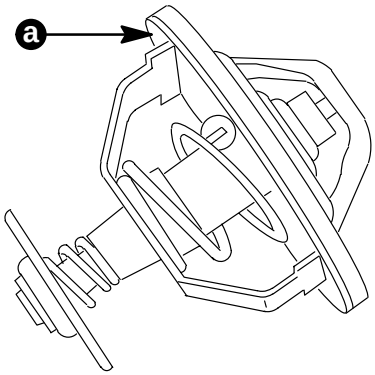


76176

a - Cover
b - Screws And Lockwashers

Testing

1. Clean thermostat in soap and water to remove any deposits or debris.
2. Inspect thermostat for corrosion or other visible damage.
3. If thermostat is suspected of producing insufficient engine temperature, check thermostat for leakage by holding it up to lighted background. Light leakage around the thermostat valve indicates that thermostat is not closing completely and should be replaced. (A small amount of leakage at one or two points around the valve perimeter is acceptable.)

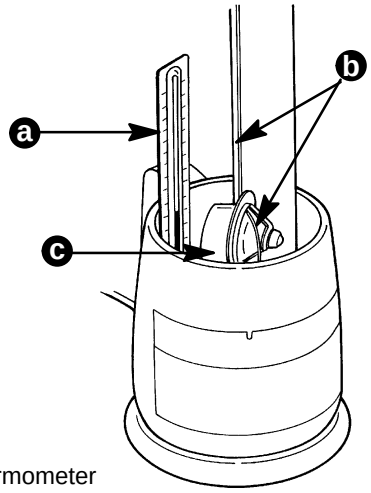


76176

a - Check for Light Leakage Around Perimeter of Valve

4. Check opening and closing temperature of thermostat (using a tester similar to the one shown), as follows:
   a. Fill tester to within 1 in. (25 mm) of top with tap water. Do not use distilled water.

b. Open thermostat valve and insert nylon string. Position thermostat on nylon string so that it will be just below water level when suspended, then allow valve to close. Suspend thermostat in water.



72675

a - Thermometer
b - Nylon String
c - Thermostat

c. Place thermometer in container and position so that bottom of thermometer is even with bottom of thermostat. Do not allow thermometer to touch container.

IMPORTANT: When performing procedures “d” through “f,” water must be agitated thoroughly to obtain accurate results.

d. Plug in tester and observe temperature at which thermostat opens (thermostat drops off thread). Thermostat must open at specified temperature stamped on thermostat.

e. Continue to heat water until a temperature 25°F (14°C) above temperature specified on thermostat is obtained. Thermostat valve must be completely open at this temperature.

f. Unplug tester and allow water to cool to a temperature 10°F (5°C) below specified temperature on thermostat. Thermostat must be completely closed at this temperature.

g. Replace a thermostat that fails to meet all of the preceding tests.

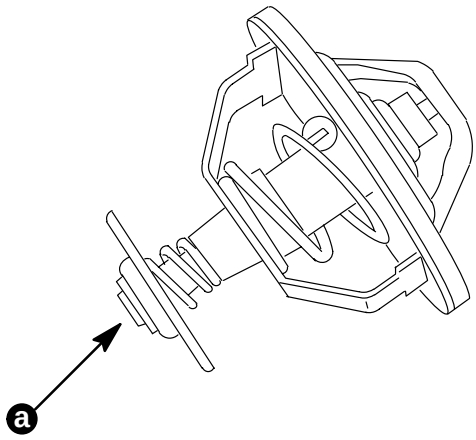
Installation

⚠CAUTION

Do not operate engine without cooling water being supplied to the seawater pickup pump, or pump impeller will be damaged.

1. Clean gasket surfaces on engine block and thermostat housing.
2. Install thermostat into engine block as shown.

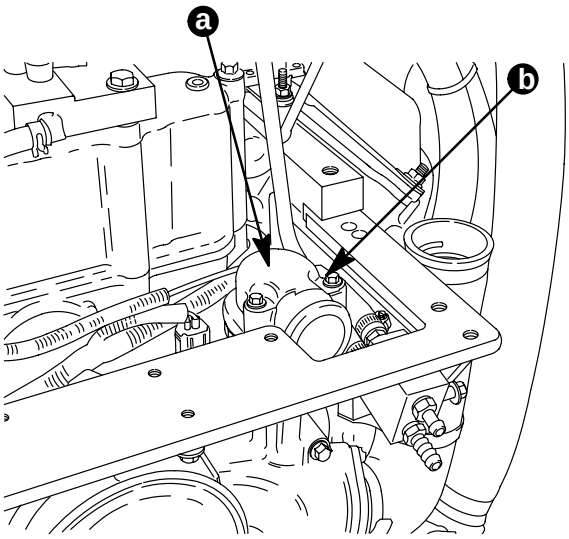
IMPORTANT: Use only factory-type thermostat. Use of other than original style thermostat could result in improper by-pass of coolant inside cylinder block.



76176

a - Install Thermostat with This End Toward Engine Block

3. Position gasket on engine block and reinstall thermostat housing. Torque bolts to 20 lb. ft. (27 N·m).



76141

a - Cover
b - Screws And Lockwashers

⚠CAUTION

Avoid seawater pickup pump impeller damage. DO NOT operate engine without cooling water being supplied to seawater pickup pump.

4. With boat in the water and/or cooling water properly supplied to seawater pickup pump, start engine and inspect for leaks.

Changing Coolant

NOTICE

For information and procedures on draining the seawater cooled section, refer to Section 6A. For cold weather or extended storage, refer to SECTION 1B.

Closed Cooled Section

Closed cooled section of cooling system should be kept filled year-round with recommended coolant solution. Do not drain closed cooled section for storage, as this will promote rusting of internal surfaces. If engine will be exposed to freezing temperatures, make sure that closed cooled section is filled with Quicksilver Premixed Marine Engine Coolant, to protect engine to lowest temperature to which it will be exposed. If necessary, change coolant.

Coolant Recommendations

⚠CAUTION

Alcohol or Methanol base antifreeze or plain water are not recommended for use in fresh water section of cooling system at any time.

It is recommended that the coolant section of closed cooled section be filled with **Quicksilver Premixed Marine Engine Coolant.**

NOTE: *The premixed formula listed above* ***requires no mixing with water*** *or other additives. The low silicate formula prevents silicate gelling which can restrict engine cooling passages. Engine coolant provides protection down to -33° F. (-38° C).*

IMPORTANT: Quicksilver Premixed Marine Engine Coolant contains special low silicate ethylene glycol, special additives, and purified water. Use of other coolant may cause fouling of the heat exchangers, and overheating of the engine.

Change Intervals

Drain and flush coolant from the closed cooled section at least every two years or whenever exhaust gases have entered the system.

Draining Instructions

⚠ WARNING

Allow engine to cool before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

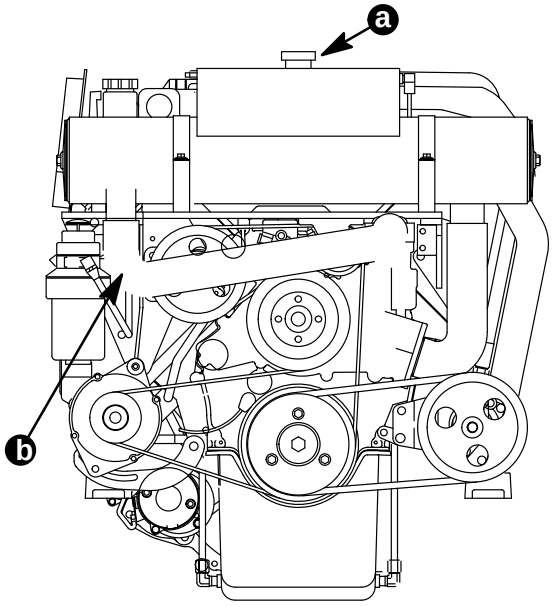
IMPORTANT: A wire should be inserted into drain holes to ensure that foreign material is not obstructing the drain holes.

IMPORTANT: Engine must be as level as possible to ensure complete draining of cooling system.

IMPORTANT: Closed cooled section must be kept filled year round with recommended coolant. If engine will be exposed to freezing temperatures, make sure closed cooled section is filled with an ethylene glycol antifreeze and water solution properly mixed to protect engine to lowest temperature to which it will be exposed.

IMPORTANT: Do not use Propylene Glycol Antifreeze in the closed cooled section of the engine.

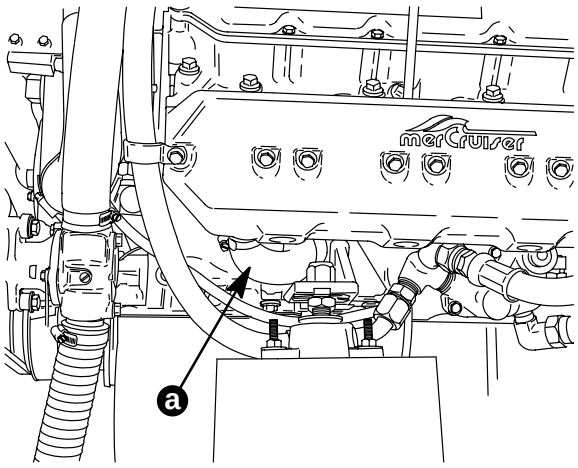
1. Remove pressure cap from coolant tank.
2. Remove the bottom hose from the heat exchanger.



76186

a - Cap
b - Bottom Hose

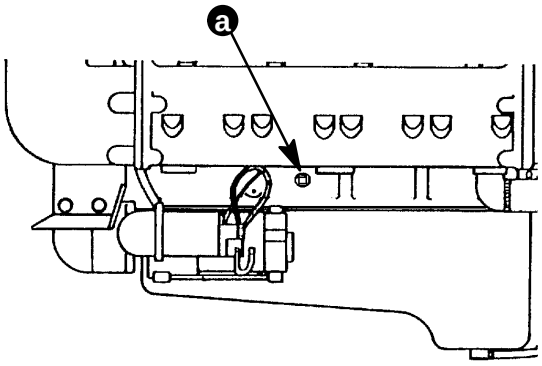
3. Remove the manifold hoses (port and starboard) and drain.



76113

a - Manifold Hoses

4. Remove port and starboard drain plugs from from the cylinder block and allow coolant to drain.



73255

a - Drain Plugs (Port and Srarboard)

5. After coolant has drained completely, coat threads of drain plugs with Quicksilver Perfect Seal and reinstall. Tighten securely.
6. Install manifold hoses. Tighten clamps securely.
7. Install bottom hose onto heat exchanger. Tighten clamp securely.
8. Remove coolant recovery bottle from mounting bracket and pour out coolant.
9. If required, clean system as outlined in “Cleaning System”.
10. Fill system as outlined in “Filling Closed Cooled Section”.

Cleaning Closed Cooled Section

Closed cooled section of cooling system should be cleaned at least once every two years or whenever decreased cooling efficiency is experienced.

A good grade automotive cooling system cleaning solution may be used to remove rust, scale or other foreign material. Refer to “Specifications”. Always follow manufacturer’s instructions for the cleaner.

If closed cooled section is extremely dirty, a pressure flushing device may be used to flush out remaining deposits. Flushing should be done in direction opposite normal coolant flow to allow water to get behind deposits and force them out. Refer to instructions which accompany flushing device for proper hookup and flushing procedure.

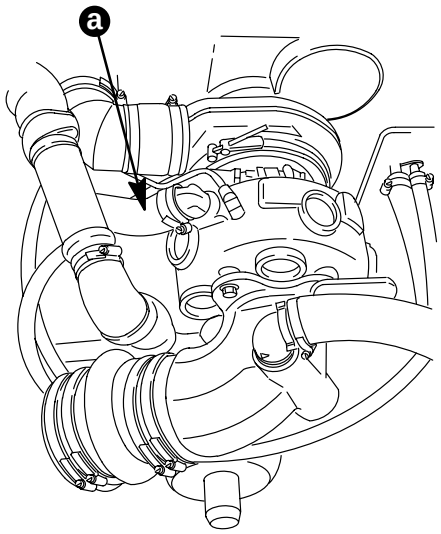
1. Drain coolant from engine as previously outlined.

NOTE: *Properly dispose of old coolant.*

2. Add one liter of Quicksilver Cooling System Cleaner 92-814825 or add Fleetgaurd Restore CC2610 to cooling system following the manufacturer’s instructions.
3. Fill the cooling system with tap water to within 1/2 to 3/4 in. (13 - 19 mm) of bottom of filler neck.

NOTE: *During system cleaning leave auxiliary heater, if so equipped, connected to engine. Not cleaning the heater will otherwise contaminate the engine when reconnected.*

4. Operate the engine in open water at wide open throttle at normal operating temperature for thirty minutes minimum to circulate cleaner.
5. Stop engine and after cool down, drain cleaner from cooling system.
6. Remove thermostat housing and thermostat. Temporarily install cover.
7. Flush closed cooling system as follows:
   a. Remove return hose (from turbocharger-to-heat exchanger) from fitting and install an adaptor suitable for connecting a tap water hose.



76132

a - Return Hose

   b. Attach tap water hose to adaptor.
   c. Place loose end of return hose into a container.
   d. Run tap water through engine until discharge water is clean.
   e. Remove water tap hose and adaptor.

NOTE: *Properly dispose of contaminated cleaner.*

   f. Install return hose to turbocharger fitting.

8. Refer to “Filling Closed Cooling Section” and refill with engine coolant. Refer to SECTION 1B for coolant recommendations.

Filling Closed Cooled Section

NOTICE

See "Specifications" for approximate closed cooled section capacity and coolant recommendation.

⚠WARNING

Do not remove coolant cap when engine is hot. Coolant may discharge violently.

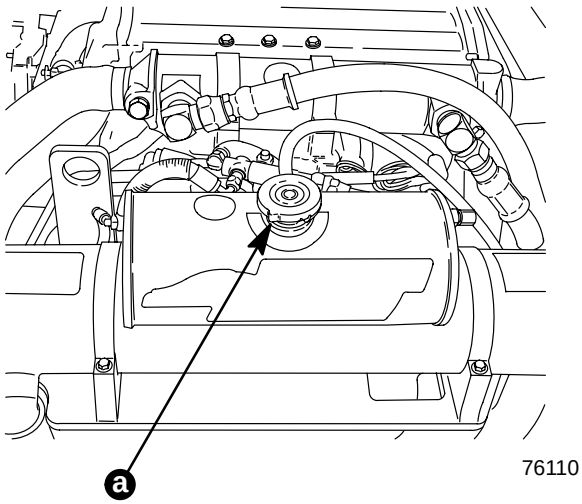
⚠CAUTION

Alcohol or Methanol based antifreeze or plain water are not recommended for use in fresh water section of cooling system at any time.

⚠CAUTION

Front of engine should be higher than rear to purge trapped air out of the system during initial filling. This will minimize the possibility of air being trapped in the closed cooled section which can cause engine to overheat.

1. Remove coolant cap from heat exchanger.



a - Coolant Cap

2. Fill closed cooled section with coolant mixture through heat exchanger fill neck until coolant appears at bleeder valve.
3. Continue filling closed cooled section until coolant level is 1 in. (25 mm) below filler neck.

⚠CAUTION

Avoid seawater pickup pump impeller damage and subsequent overheating damage to stern drive unit. DO NOT operate engine without water being supplied to seawater pickup pump.

⚠CAUTION

Models with belt driven seawater pickup pump must be in the water when running engine because garden hose will not supply enough water to system at higher RPM.

4. With pressure cap off, start engine and run at fast idle (1500-1800 RPM). Add coolant solution to heat exchanger, as required, to maintain coolant level 1 in. (25 mm) below filler neck.
5. After engine has reached normal operating temperature (thermostat is fully open), and coolant level remains constant, fill heat exchanger to bottom of filler neck.
6. Observe engine temperature gauge to make sure that engine operating temperature is normal. If gauge indicates excessive temperature, stop engine immediately and examine for cause.
7. Install pressure cap on heat exchanger.
8. Remove cap from coolant recovery reservoir and fill to FULL mark with coolant solution. Reinstall cap.
9. With engine still running, check hose connections, fittings and gaskets for leaks. Repeat Step 4.

IMPORTANT: Engine overheating is often due to air being trapped in closed cooled section. Purge air by running engine at 2000 RPM for 10 minutes.

⚠WARNING

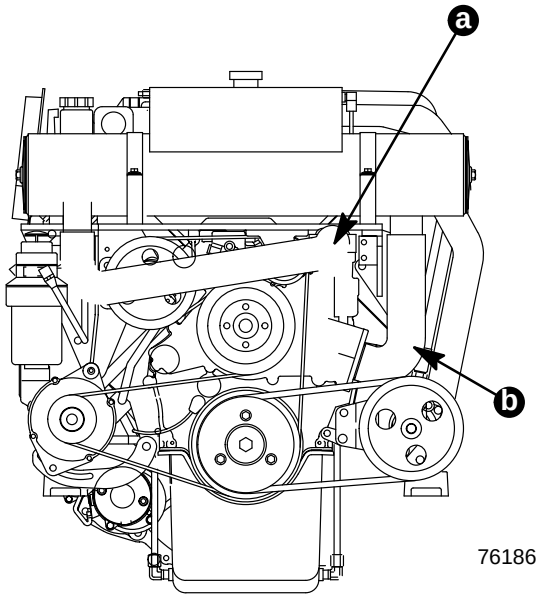
Allow engine to cool before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

10. Recheck coolant level after first open-throttle boat test and add coolant, if necessary.
11. Maintain coolant level in coolant recovery reservoir between ADD and FULL marks with engine at normal operating temperature.

Water Circulating Pump Replacement

Removal

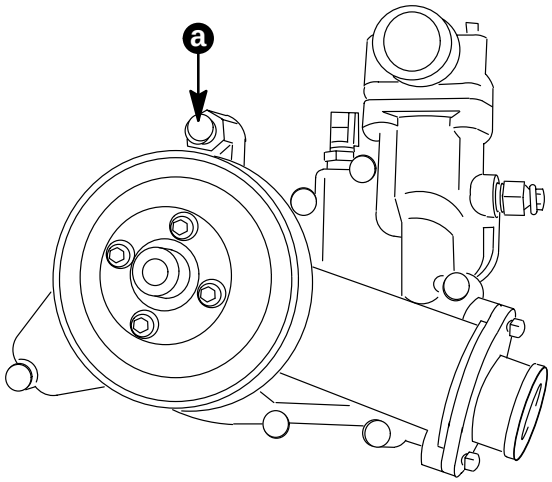
1. Refer to “Draining Seawater Cooled Section” in SECTION 6A and drain the seawater section.
2. Refer to “Changing Coolant - Draining Instructions” in this section and drain the closed cooled section.
3. Disconnect both hoses from heat exchanger.



76186

a - Hose To Thermostat Housing
b - Hose To Circulating Pump

4. Remove heat exchanger. See “Heat Exchanger Removal” later in this section.
5. Remove seawater pump belt and alternator belt. Refer to SECTION 1B.
6. Remove circulating pump attaching bolts and remove circulating pump and seal. Discard used seal.

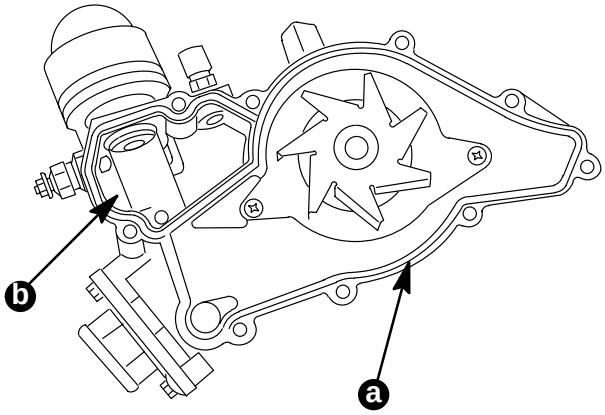


76179

a - Bolts (7)

Cleaning and Inspection

1. Clean gasket surfaces on circulating pump, spacer and engine block.
2. Inspect circulating pump for blockage, cracks, sand holes, corrosion or other damage. Inspect pump impeller for cracks and erosion. Replace complete pump if any damage exists.

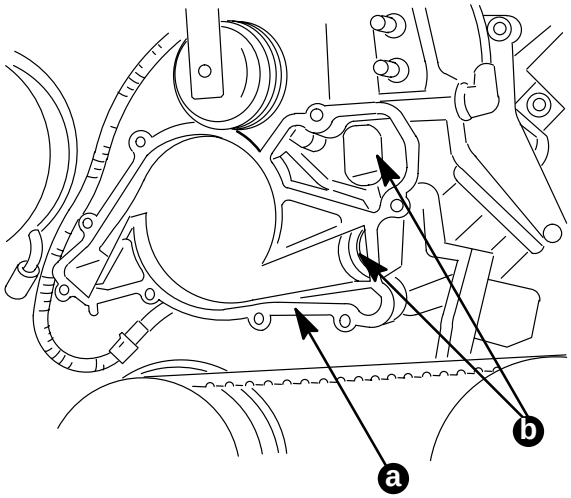


76178

a - Sealing Surface
b - Passages

3. Inspect impeller shaft and bearings for excessive side play. If play can be felt, replace complete pump.

4. Inspect housing for blockage, cracks, sand holes, corrosion or other damage. Replace spacer if any damage exists.



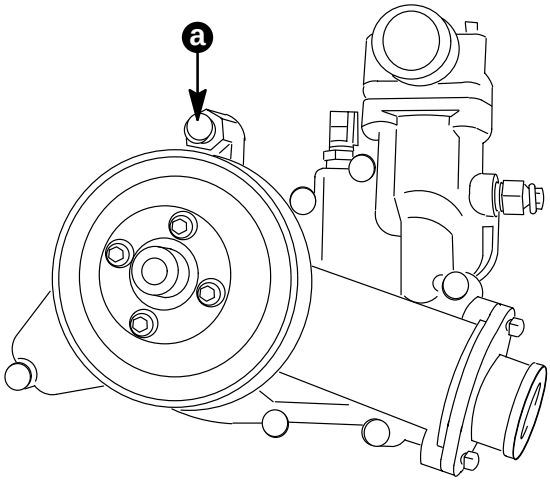
76180

a - Sealing Surface
b - Passages

5. Inspect pump pulley for bends, cracks, corrosion or other physical damage. Inspect pulley for rotational trueness. Replace pulley if damaged or untrue.

Installation

1. Coat seal with a thin coat of Permatex Aviation Sealer No. 3.
2. Apply Permatex Aviation Sealer No. 3 to threads and heads of ALL screws prior to installation.
3. Install circulating pump (with new seal) using attaching screws. Screws are in two different lengths - 3 in. (76 mm) and 4 in. (102 mm. DO NOT fit the longer screw in the place of a short screw.



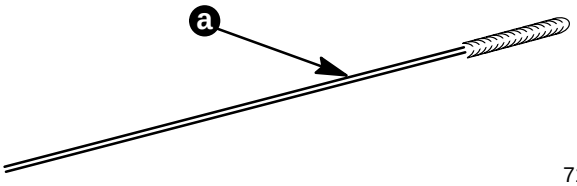
76179

a - Bolts (7)

4. Torque fasteners to 168 lb. in. (19 N·m).
5. Connect hoses to circulating pump and thermostat housing. Tighten hose clamps securely.
6. Install belts. Refer to SECTION 1B.
7. Refer to “Filling Closed Cooled Section” and fill the closed cooled section.

Cleaning Heat Exchangers and Coolers

1. Clean tubes in heat exchanger and coolers by running a suitable wire brush thru each tube.

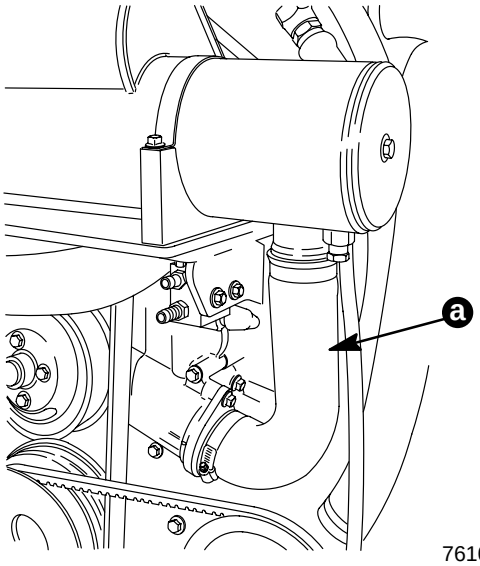


71724

2. Rinse out heat exchanger and cooler tubes with tap water from a hose to remove loosened particles.
3. Replace unit if it cannot be satisfactorily cleaned.

Heat Exchanger Removal

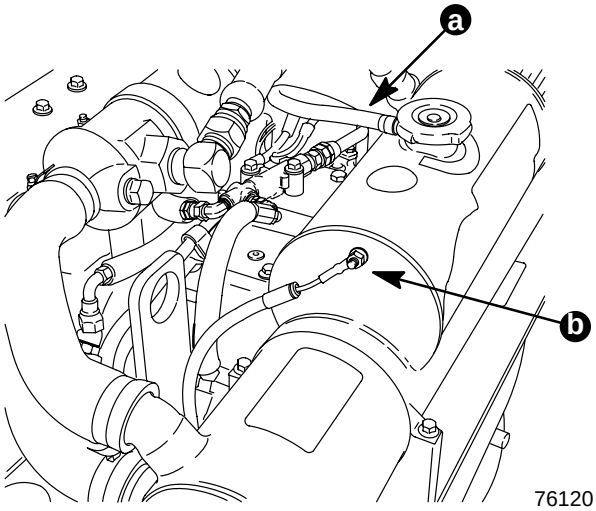
1. Drain seawater from seawater side of system.
2. Drain coolant from closed side of system.
3. Disconnect hoses from all locations shown.



76108

a - Hose - To Circulating Pump

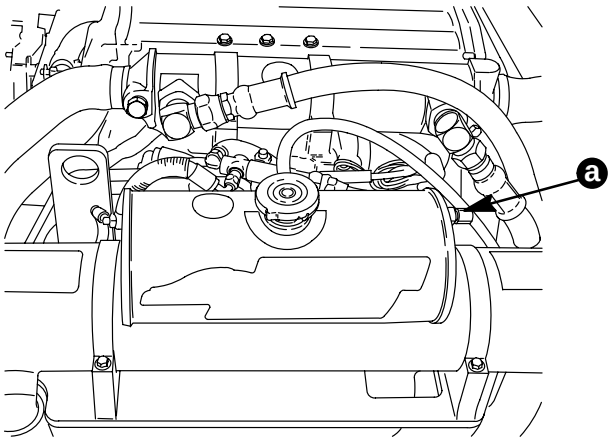
4. Disconnect continuity ground (-) wire from upper side of tank.



76120

a - Coolant Overflow Hose
b - Continuity Wire

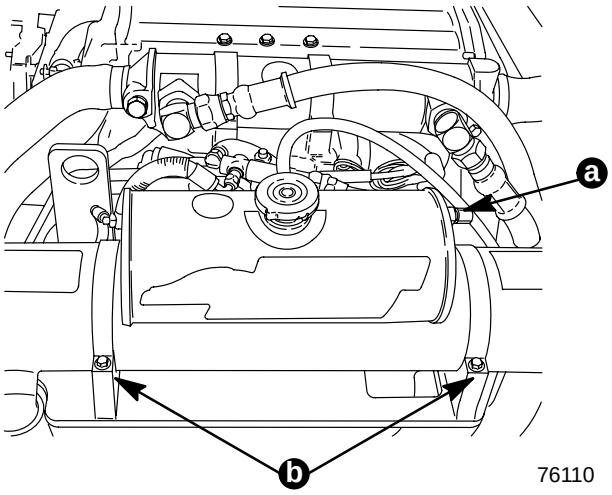
5. Disconnect the coolant bleed line that comes from turbocharger.



76110

a - Bleed Line From Turbocharger

6. Remove hardware that secures heat exchanger to bracket.

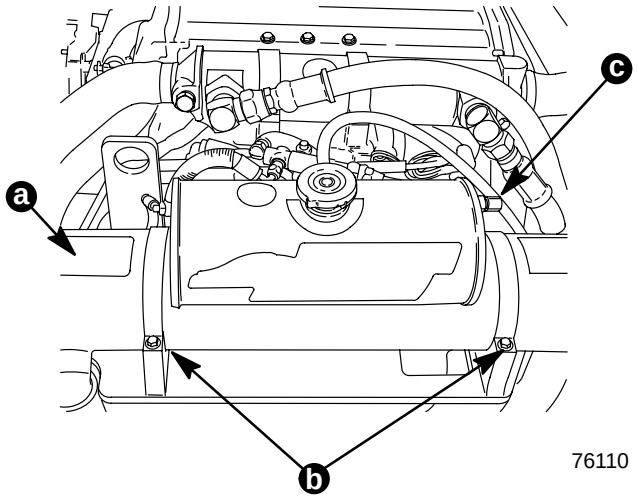


a - Heat Exchanger
b - Bolts

Heat Exchanger Installation

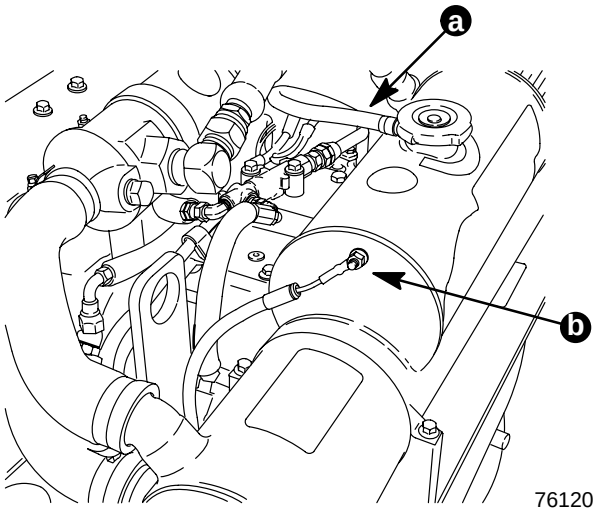
NOTE: *If not already accomplished, remove sacrificial anode from port fitting in tank. Replace if more than 50% deteriorated. Refer to SECTION 1B, "Anodes".*

1. Install drain plug (sacrificial anode) in tank, if not already fitted. Tighten securely.
2. Install heat exchanger to mounting brackets using fasteners and hardware. Be certain pressure cap is upright and horizontal. Torque fasteners to 30 ft. lb. (41 N·m).
3. Reconnect all hoses to coolant tank/heat exchanger and tighten each hose clamp securely.
4. Connect turbocharger vent line at fitting on tank. Tighten securely.



a - Coolant Tank/Heat Exchanger
b - Mounting Fasteners and Hardware (4 Places)
c - Turbocharger Vent Pipe and Fitting

5. Connect continuity ground (-) wire to upper side of tank.



a - Coolant Overflow Hose
b - Continuity Wire

6. Refer to "Filling Closed Cooled Section" in SECTION 6B and fill the closed coolant system with specified coolant mixture.

Auxiliary Hot Water Heater Installation

IMPORTANT: When connecting a cabin heater or hot water heater, certain requirements must be met:

- **Supply hose (from engine to heater) and return hose (from heater to engine) MUST NOT EXCEED 5/8 in. (15.8 mm) I.D. (inside diameter).**
- **Heater MUST BE LOWER than fill cap on the heat exchanger. If the heater is higher than the fill cap on the heat exchanger and some coolant is lost in the system, an air pocket may form in the closed cooled section. This, in turn, can cause the engine to overheat.**
- **Make heater connections ONLY at locations described in the following instructions.**
- **Check complete system for leaks after heater is connected into cooling system.**
- **Check for overheating condition (of engine) after heater is connected.**

1. Refer to “Changing Coolant - Draining Instructions”; drain closed cooled section.
2. Inspect for appropriate location of supply hose as shown.
3. Secure fittings and hoses, as required. Ensure hoses do not rub or chafe against engine components.
4. With boat in water, start engine and check for leaks and overheating.

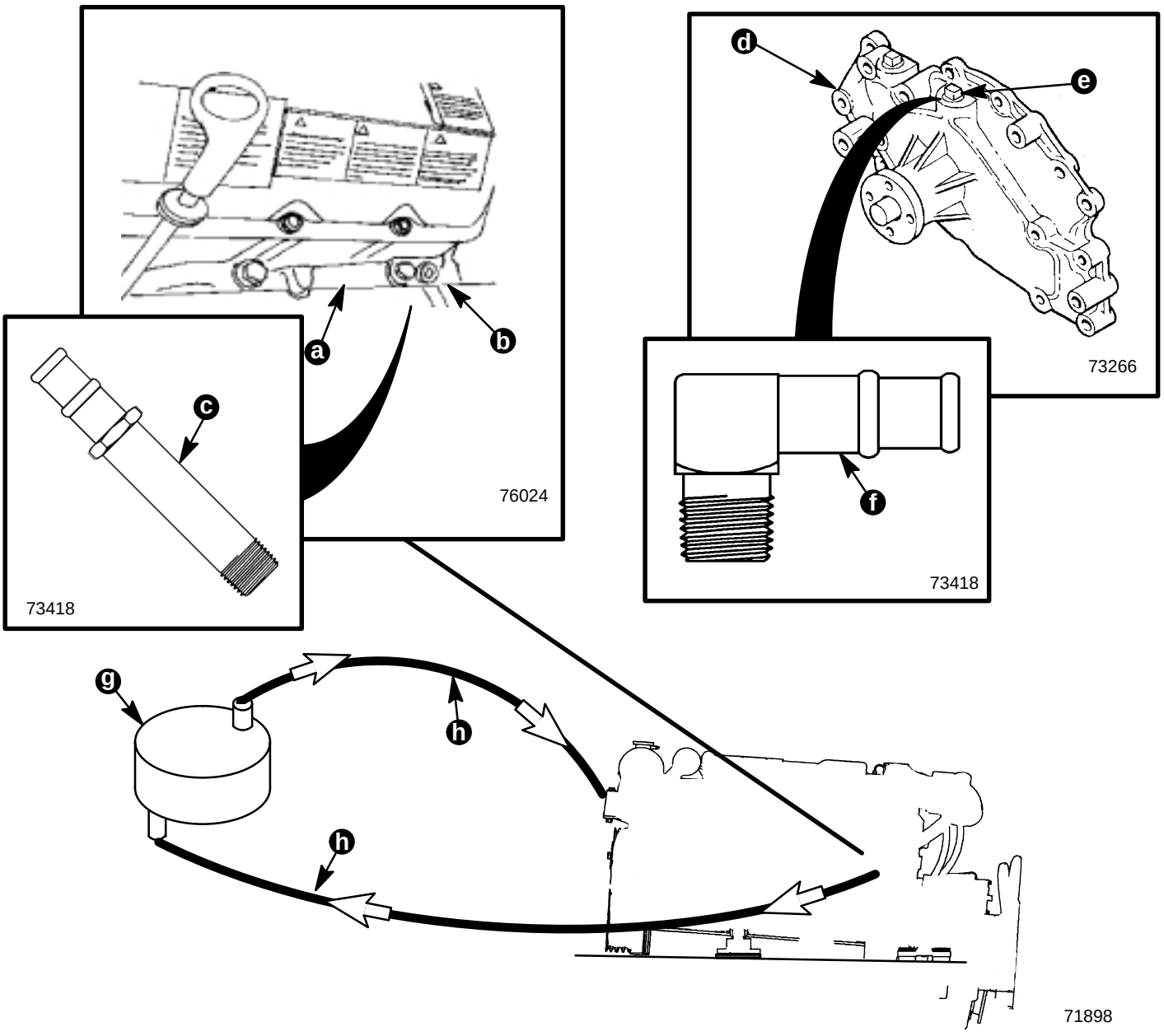
NOTE: *See “Flow Diagram - Auxiliary Hot Water Heater Connection” following.*

Flow Diagram - Auxiliary Hot Water Heater Connection

A straight hose coupler fitting replaces the plug in starboard cylinder head, located beneath cover of exhaust manifold, as shown, delivers hot water TO the heater.

A 90° hose coupler fitting replaces the plug located on top of the engine water circulating pump, as shown , delivers return water FROM the heater.

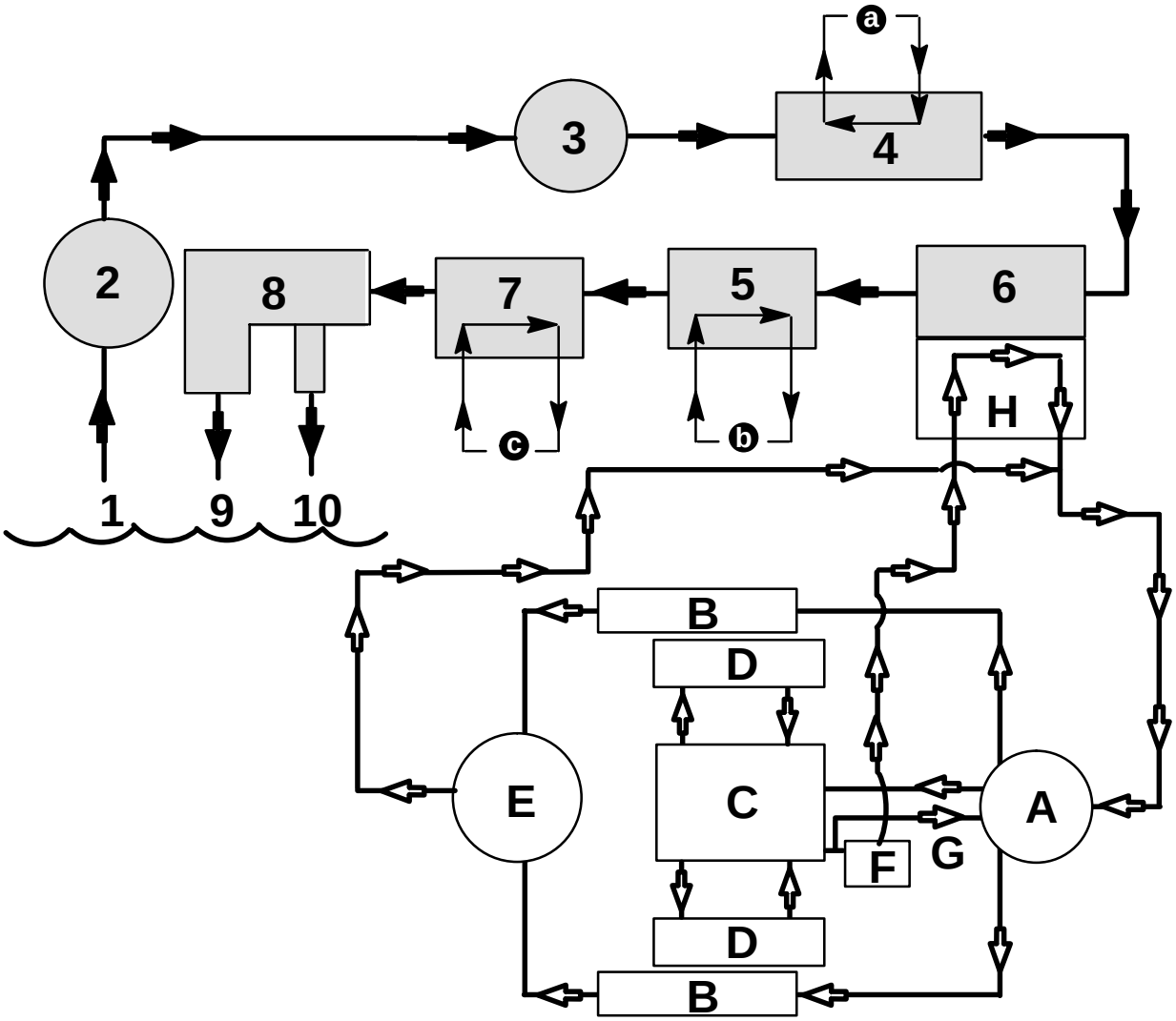
NOTE: *Pump shown removed for visual clarity only.*



a - Cylinder Head - On Port Rear Side
b - Plug (Existing)
c - Straight Hose Coupler Fitting (From Kit)
d - Engine Water Circulating Pump
e - Plug (Existing)
f - 90 Degree Hose Coupler Fitting (From Kit)
g - Auxiliary Hot Water Heater
h - Hoses

Quicksilver Auxiliary Water Heater Adaptor Kit (806027A1) Shown

Water Flow Diagram



76205

SEAWATER COOLING CIRCUIT (RAW WATER)

1 - Seawater Inlet (Thru Drive)
2 - Seawater Strainer
3 - Seawater Pump
4 - Aftercooler
5 - Engine Oil Cooler
6 - Heat Exchanger (Seawater Circuit)
7 - Power Steering Fluid Cooler
8 - Exhaust Pipe Water Jacket
9 - Seawater Outlet (Exhaust Pipe)
10- Seawater Outlet (Overboard Discharge Fitting)

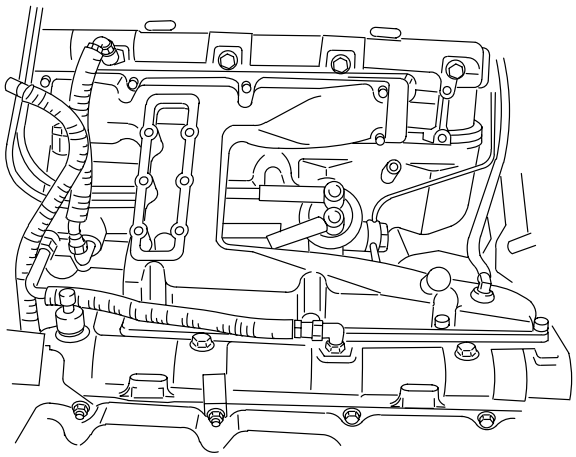
CLOSED COOLING CIRCUIT (FRESH WATER/COOLANT)

A - Circulating Pump - Closed Coolant
B - Exhaust Manifolds
C - Engine Crankcase
D - Cylinder Heads
E - Turbocharger
F - Thermostat
G - Bypass
H - Heat Exchanger (Closed Cooling Circuit)

FLOW OF :

ⓐ ENGINE AIR
ⓑ ENGINE OIL
ⓒ POWER STEERING FLUID

INTAKE AND EXHAUST SYSTEM



76181

7

A

INTAKE MANIFOLD AND AFTERCOOLER

Index

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Torque Specifications

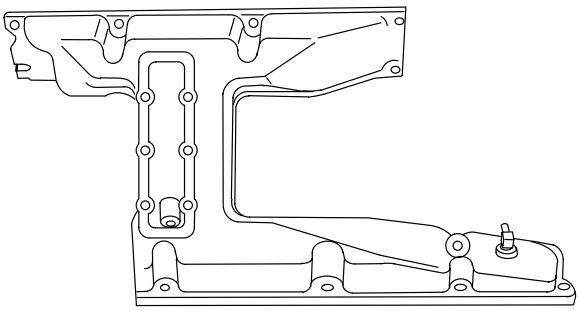
Item/Fastener Location	Lb. In.	Lb. Ft.	N·m
Intake Manifold Bolts		24	33
Aftercooler Side Covers		21	28
Aftercooler-to-Manifold		30	41

Sealants

Description	Part Number
Walker - T95® Sealant	Obtain Locally (Navistar Part Number 1816593C1 or GM Part Number 12345366)

Description

The D7.3L D-Tronic engine uses an aftercooler (sometimes referred to as an “intercooler” or “air cooler”) to cool the intake air before it enters the cylinders. Seawater is pumped through tubes in the aftercooler, cooling the air as it flows around the tubes. The cooled air is then directed to the intake manifold and finally the cylinder.

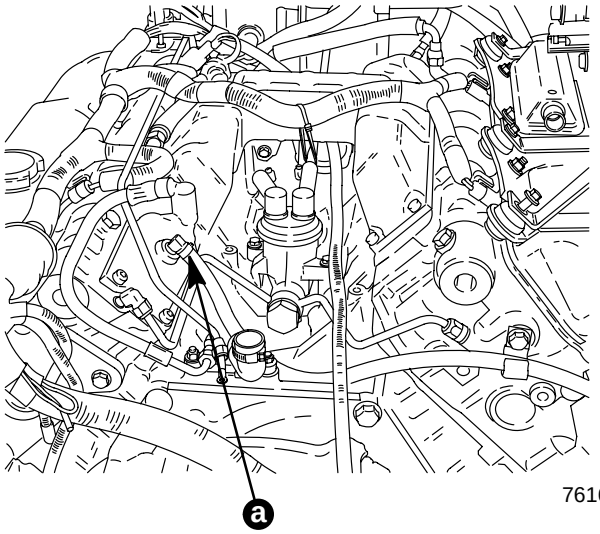


76182

Intake Manifold

Removal

1. Remove aftercooler as outlined in this section.
2. Remove turbocharger as outlined in SECTION 7C.
3. Disconnect MAP sensor hose from fitting on manifold.

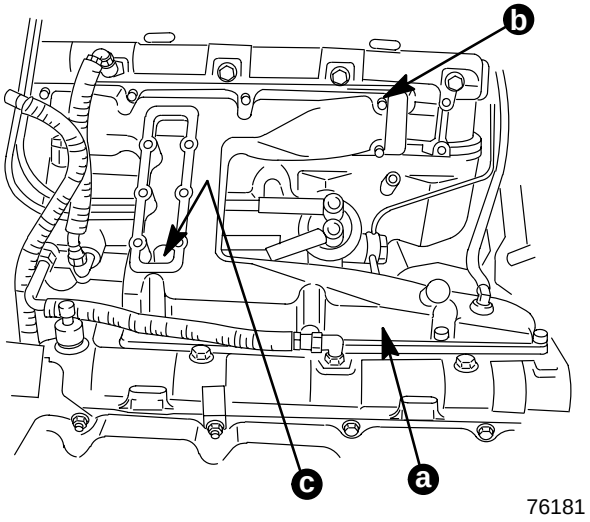


a - MAP Sensor Hose

IMPORTANT: Bolts are of several lengths and should be suitably marked, or otherwise referenced, during disassembly. This will ensure installation in the same locations during reassembly.

4. Remove intake manifold bolts and remove intake manifold and gaskets.

NOTE: *The forward, outer bolt on the port side is located inside the intake manifold. The bolt can be accessed through the opening in the intake manifold.*



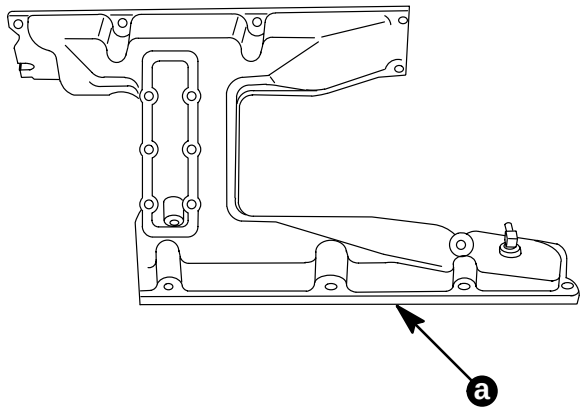
a - Manifold
b - Bolts (8 On Each Side)
c - One Bolt Is Accessed Through Opening

Cleaning and Inspection

1. Clean intake manifold using a suitable non-caustic solvent.
2. Clean all RTV and gasket material from mating surfaces using parts solvent cleaner. Be sure all mating surfaces are free of oil.
3. Dry surfaces using filtered compressed air.
4. Visually inspect the intake manifold for cracks.
5. Place mounting surface (outlets) of manifold on smooth surface and check for warpage.
6. Replace manifold if cracked or warped.

Installation

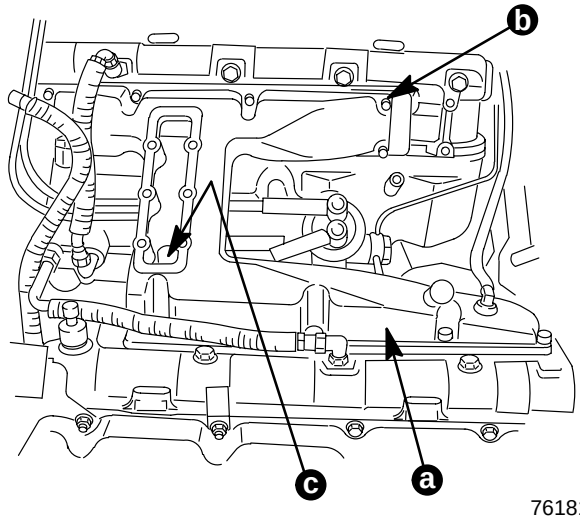
1. Install new gaskets between intake manifold and cylinder head.
2. Install intake manifold.



76182

a - Manifold

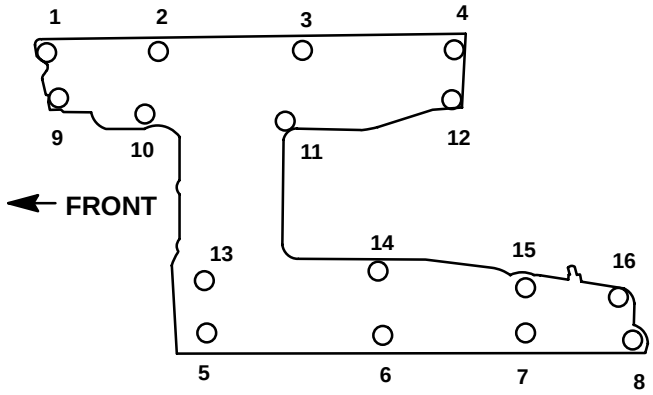
3. Install bolts in same location (as marked during removal).



76181

a - Manifold
b - Bolts (8 On Each Side)
c - One Bolt Is Accessed Through Opening

4. Tighten all bolts until they are contacting manifold.
5. Tighten all bolts securely ***in numbered sequence*** shown.
6. Torque bolts to 18 lb. ft. (24 N·m) ***in numbered sequence*** shown.



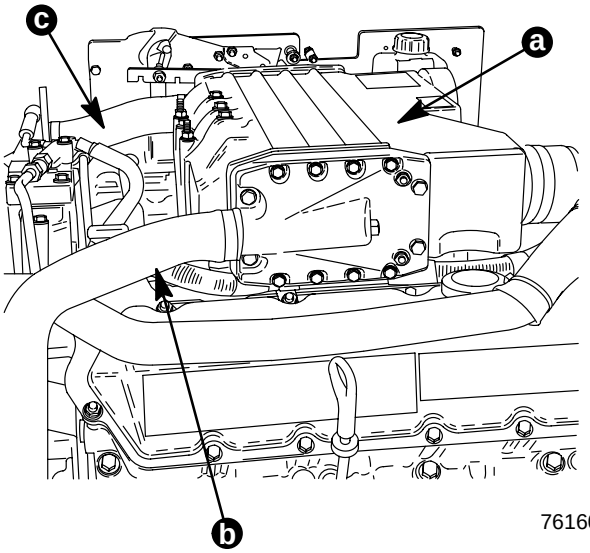
76210

7. Connect MAP sensor hose to fitting on manifold.
8. Install turbocharger as outlined in SECTION 7C.
9. Install aftercooler as outlined in this section.

Aftercooler

Removal

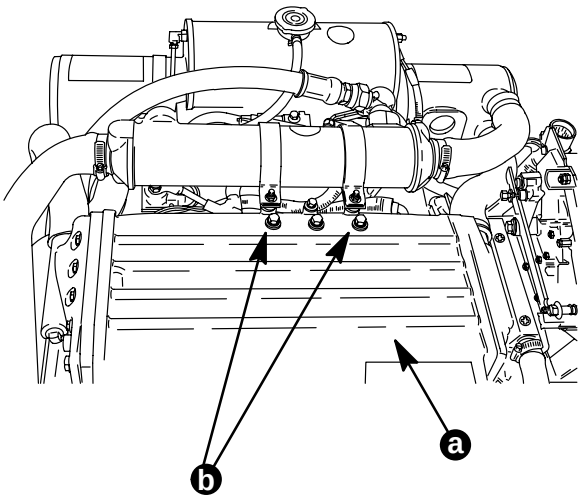
1. Remove turbocharger as outlined in SECTION 7C.
2. Disconnect seawater hoses.



76160

a - Aftercooler
b - Hose (Port Side)
c - Hose (Starboard Side)

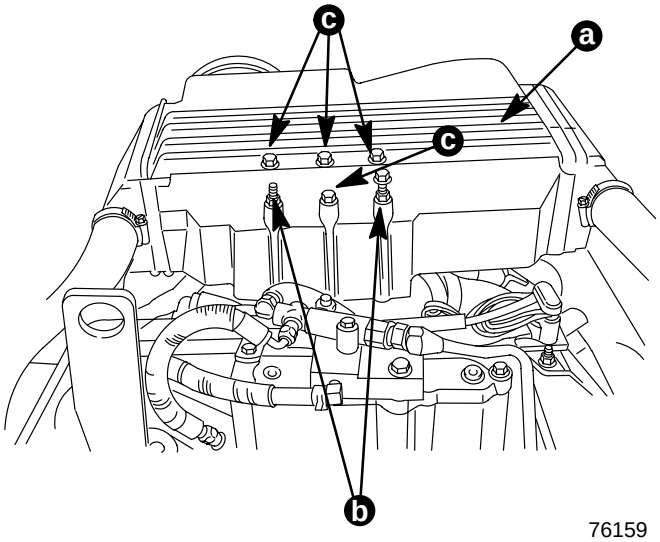
3. Remove oil cooler clamps.



76123

a - Aftercooler
b - Clamps

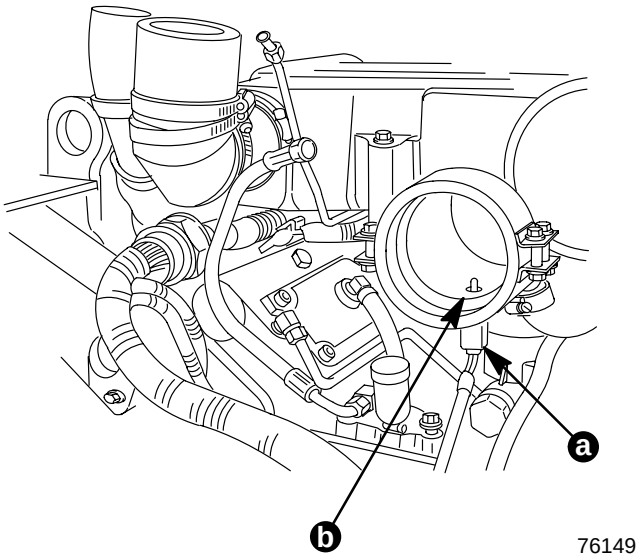
4. Remove fasteners that secure aftercooler. Make note of proper position for reassembly.



76159

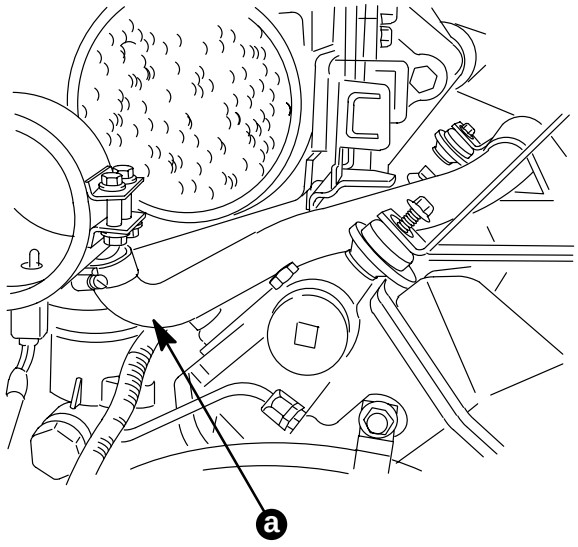
a - Aftercooler
b - Studs And Nuts
c - Bolts

5. Disconnect wires from Intake Air Temperature (IAT) Sensor.



a - Harness Connector
b - IAT Sensor

6. Disconnect vent hose that comes from starboard valve cover.

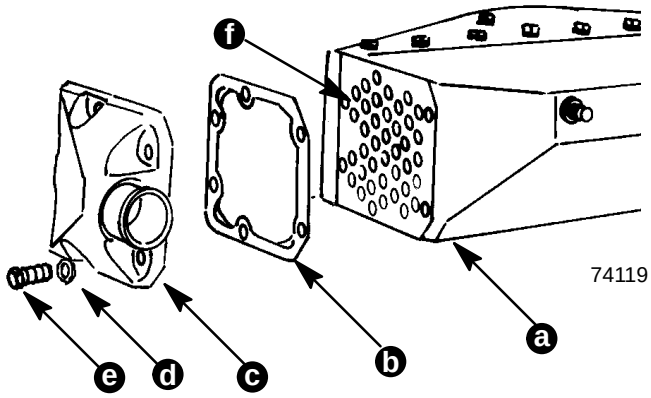


a - Vent Hose

7. Remove aftercooler and gasket.

Cleaning and Inspection

1. Remove end cap from inlet and outlet side of aftercooler and inspect passages. Note that washers are special, copper sealing washers.

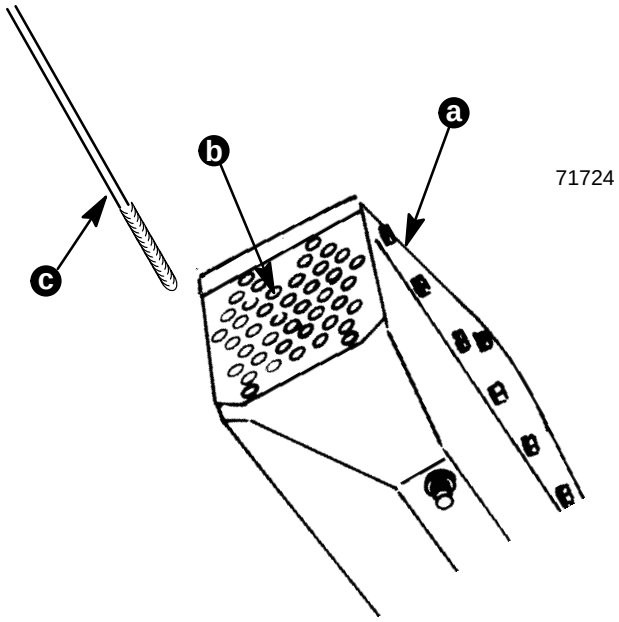


a - Aftercooler
b - Gasket
c - End Cover (Starboard Shown Removed, Port Similar)
d - Sealing Washer
e - Screw
f - Passages

2. Inspect all parts for cracks or other damage which would render the aftercooler unserviceable.

IMPORTANT: MerCruiser does not recommend the immersion of coolers in cleaning solutions. If cleaning as instructed does not satisfactorily clear the passages, replacement of the cooler is recommended.

3. Clean water passages by inserting a suitable size wire brush into each passage. Use compressed air to blow loose particles out of water passages.



71724

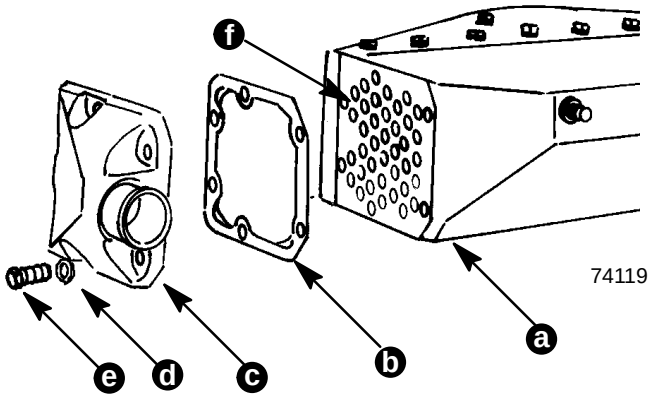
74120

a - Aftercooler
b - Passages
c - Suitable Brush

Assembly

1. Clean sealing material from mating surfaces.
2. Apply Quicksilver RTV Sealer or equivalent to mating surfaces.
3. Position new gaskets on ends of aftercooler.
4. Install end caps to cooler using fasteners and special copper sealing washers. Torque fasteners to 21 lb. ft. (28 N·m).

NOTE: *Replace any washers showing unacceptable corrosion, or wear from previous removal and tightening.*



74119

Starboard Side Shown (Port Similar)

a - Aftercooler
b - Gasket
c - End Cover (Starboard Shown Removed, Port Similar)
d - Sealing Washer
e - Screw
f - Passages

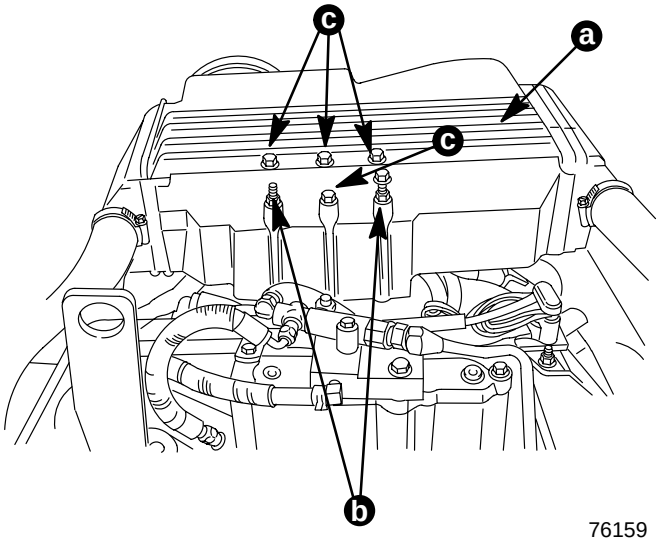
Testing

1. Test aftercooler for leaks as follows:
   a. Connect a radiator type tester or other suitable device to one end of aftercooler.
   b. Plug opposite end of aftercooler.
   c. Apply 10 PSI (70 kPa) of air pressure and submerge aftercooler into water. Air bubbles indicate a leak.
2. Clean and paint exterior surfaces as required to prevent corrosion.

Installation

1. Be certain aftercooler is clean and completely dry inside and outside before proceeding.
2. Verify that the intake-to-aftercooler gasket is in place. Install aftercooler to manifold, while guiding studs into support brackets on front of aftercooler. Torque fastener to 30 lb. ft. (41 N·m).

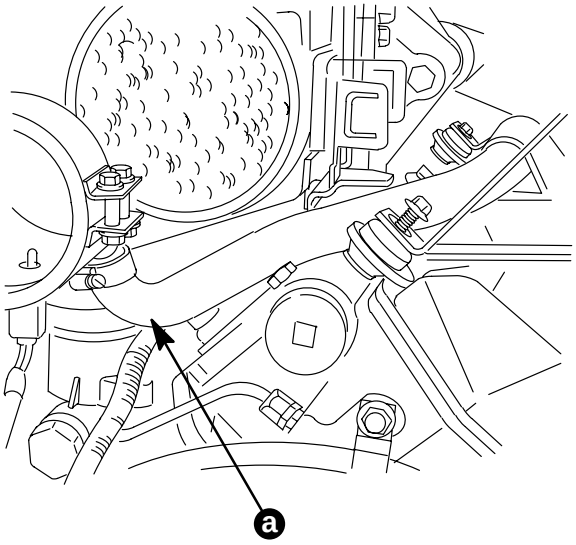
IMPORTANT: Be certain gasket is in good condition and in proper position. If not, a loss in boost pressure will occur resulting in decreased performance.



76159

a - Aftercooler
b - Studs And Nuts
c - Bolts

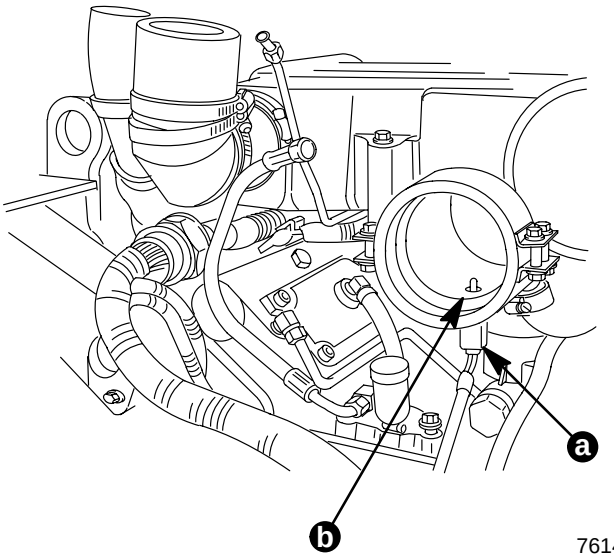
3. Connect vent hose that comes from starboard valve cover.



76161

a - Vent Hose

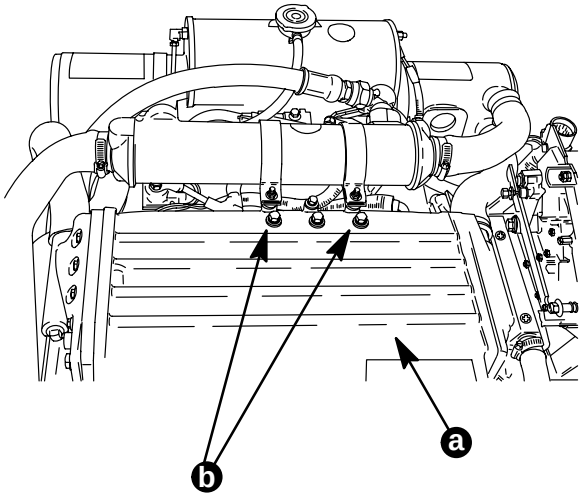
4. Connect wires to Intake Air Temperature (IAT) Sensor.



76149

a - Harness Connector
b - IAT Sensor

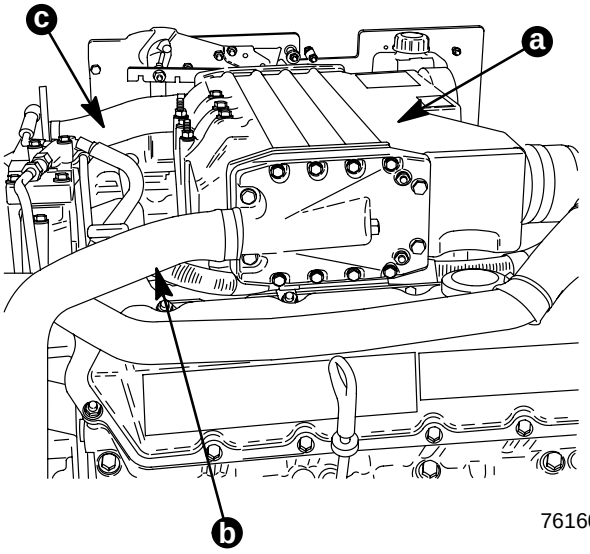
5. Install oil cooler clamps.



76123

a - Aftercooler
b - Clamps

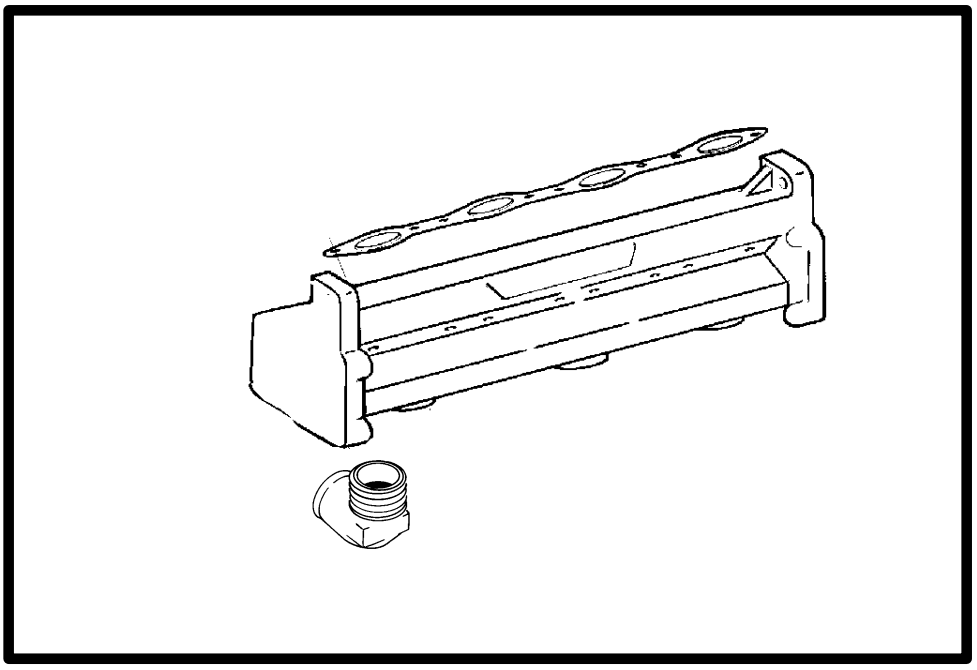
6. Connect seawater hoses.



76160

a - Aftercooler
b - Hose (Port Side)
c - Hose (Starboard Side)

INTAKE AND EXHAUST SYSTEM



7

B

EXHAUST SYSTEM

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Exhaust Manifolds	7B-4
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Installation	7B-4

Torque Specifications

Item/Fastener Location	Lb. In.	Lb. Ft.	N·m
Exhaust Cross-over Manifold		24	32
Exhaust Manifold Elbow-to-Manifold			
Exhaust Manifold-to-Cylinder Block		35	48
Exhaust Pipe-to-Gimbal Housing		20 - 25	27 - 34

Sealants

Item/Description	Part Number
Loctite Pipe Sealant with Teflon	Obtain Locally
Quicksilver Perfect Seal	92-34227--1
Quicksilver RTV Sealer	92-91601--1

Description

The D7.3L D-Tronic diesel engine is equipped with fresh water (coolant) cooled exhaust manifolds. Coolant flows from the heat exchanger to the circulating pump where it is pumped to the crankcase and to the water cooled exhaust manifolds through a spacer (plate) installed between the crankcase front plate and the circulating pump.

After leaving the water cooled exhaust manifolds it flows through the attached manifold elbows, exhaust crossover, and turbocharger. The coolant is then returned back to the heat exchanger.

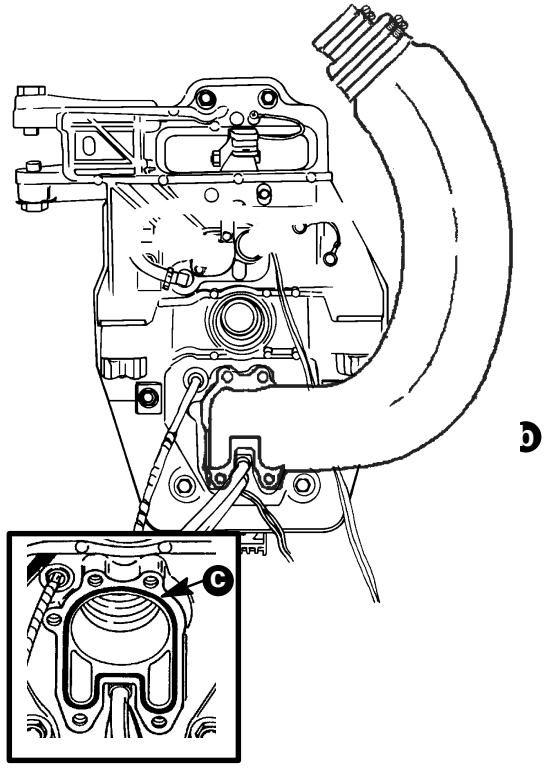
Once the exhaust gases leave through the exhaust valves they are directed through the water cooled exhaust manifolds, manifold elbows, exhaust crossover, turbocharger and then to the exhaust elbow where they join the seawater discharge to the sea.

Exhaust Pipe

Removal

IMPORTANT: Engine must be removed to gain access to exhaust pipe. Refer to SECTION 2A for engine removal and installation.

1. Remove four bolts and thick lockwashers retaining exhaust pipe to gimbal housing.
2. Remove exhaust pipe.
3. Remove O-Ring seal and discard.

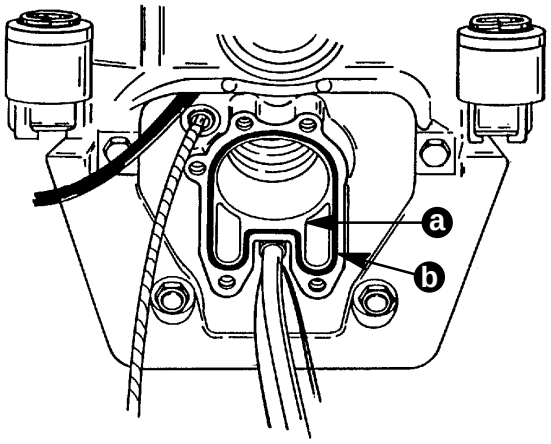


76214

a - Bolts and Thick Lockwashers (4)
b - Exhaust Pipe
c - O-Ring Seal

Installation

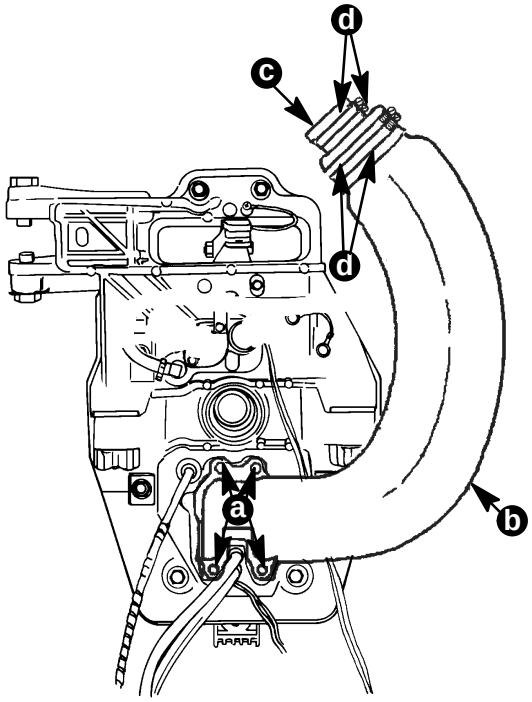
IMPORTANT: Exhaust pipe and gimbal housing assembly mating surfaces must be clean and free of nicks and scratches. O-Ring must be properly seated in groove, or water and exhaust may leak into boat.



72745

a - Mating Surface (Also, on Exhaust Pipe)
b - O-Ring

1. After cleaning mating surfaces, install new O-Ring. Be certain it is seated properly in groove of gimbal housing.
2. Hold exhaust pipe in position. Install thick washers and bolts (four each). Torque evenly in a diagonal pattern to 20-25 lb. ft. (27-34 N·m).
3. Lubricate the inside of large end of exhaust hose with a soap and water solution. Slide hose over exhaust pipe and install two hose clamps. Tighten hose clamps securely.



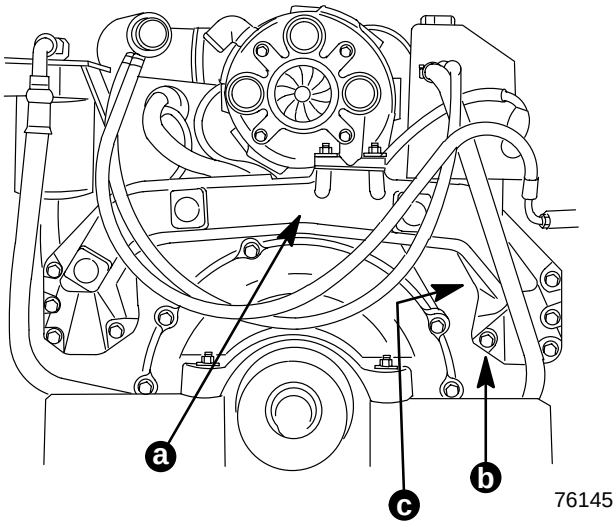
76215

a - Bolts and Thick Lockwashers (4)
b - Exhaust Pipe
c - Hose
d - Hose Clamps (2)

Exhaust Crossover Manifold

Removal

1. Drain coolant from engine. Refer to Section 6B.
2. Remove turbo charger from exhaust cross-over manifold. Refer to Section 7C.
3. Remove nuts from front side of cross-over manifold.
4. Remove cross-over manifold and gaskets.



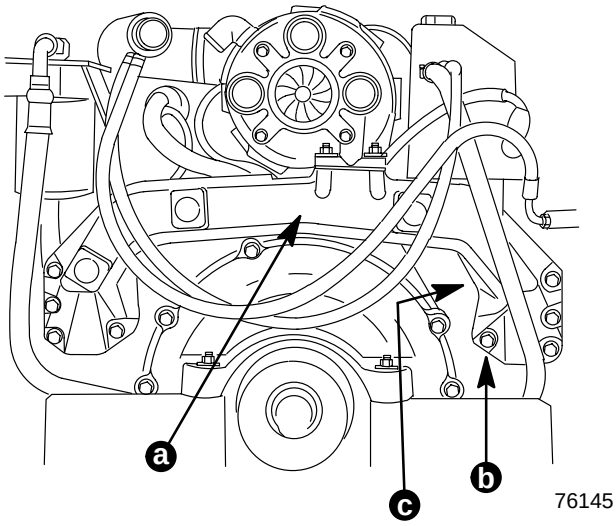
a - Cross-Over Manifold
b - Bolts (4 Each Side)
c - Nuts (1 Each Side - On Front)

Cleaning and Inspection

1. Clean gasket material from all surfaces and wash parts in solvent.
2. Inspect all parts carefully. Machined surfaces must be clean and free of all marks and deep scratches, or water and exhaust leaks may result.
3. Check water passages for foreign material. Passages must be clean for efficient cooling.
4. Check for cracks.

Installation

1. Install cross-over manifold with new gaskets.
2. Install four bolts on each side that secure it to each manifold.
3. Install nuts on front side of cross-over manifold.
4. Torque fasteners to 24 lb. ft. (32 N·m).



a - Cross-Over Manifold
b - Bolts (4 Each Side)
c - Nuts (1 Each Side - On Front)

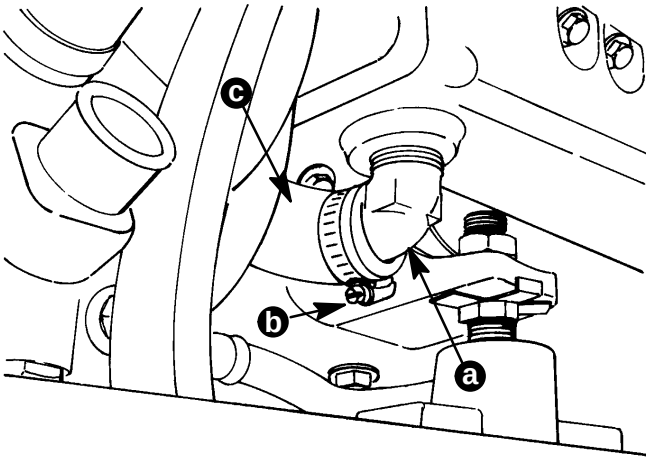
5. Install turbo-charger on exhaust cross-over manifold. Refer to Section 7C.

Exhaust Manifolds

Removal

NOTE: *Procedure is the same for both manifolds.*

1. Drain coolant from engine. Refer to Section 6B.
2. Remove turbo-charger from exhaust cross-over manifold. Refer to Section 7C.
3. Remove exhaust cross-over manifold as previously outlined in this section.
4. Disconnect hose from front fitting.



74127

Port Side Shown (Starboard Similar)

a - 90 Degree Fitting On Exhaust Manifold
b - Hose Clamp
c - Hose

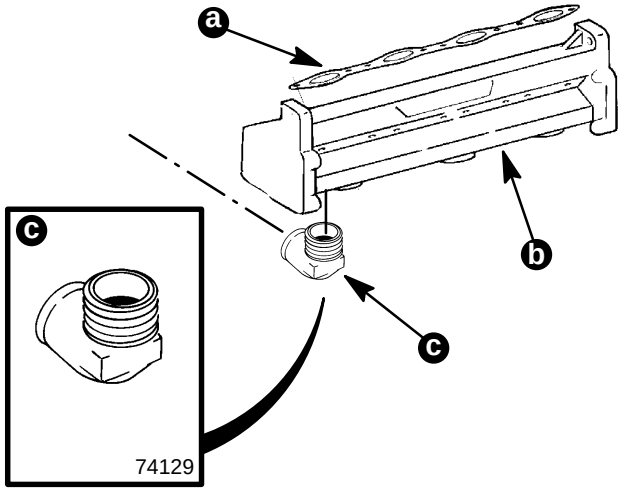
5. Remove bolts from manifold.
6. Remove manifold and gasket.

Cleaning and Inspection

1. Clean gasket material from all surfaces and wash parts in solvent.
2. Inspect all parts carefully. Machined surfaces must be clean and free of all marks and deep scratches, or water and exhaust leaks may result.
3. Check water passages for foreign material. Passages must be clean for efficient cooling.
4. Check for cracks.

Installation

1. Be certain mating surfaces of cylinder heads are clean and free of all old gasket material. Machined surfaces must not have nicks or gouges, or water and exhaust leaks may result.
2. Apply Quicksilver Perfect Seal (92-34227--1) to threads of 90° elbow fitting(s). Install and position in manifold(s) as shown. Tighten fitting securely.
3. Install gasket and exhaust manifold. Torque bolts evenly in a diagonal pattern to 35 lb. ft. (48 N·m).

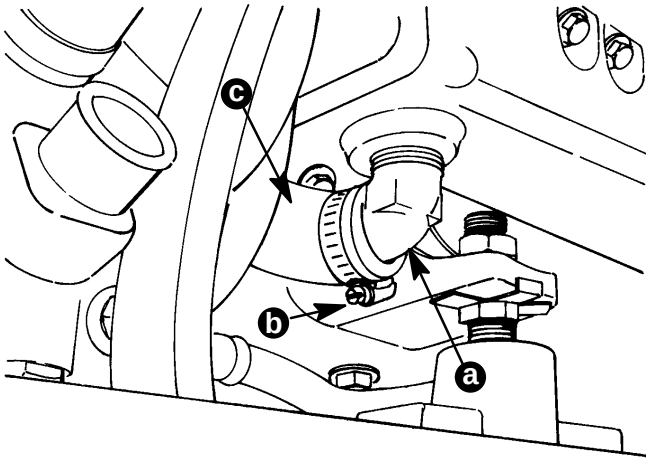


74129

Port Side Shown (Starboard Similar)

a - Gasket
b - Manifold
c - 90 Degree Fitting On Exhaust Manifold

4. Connect hose to fitting and tighten securely.



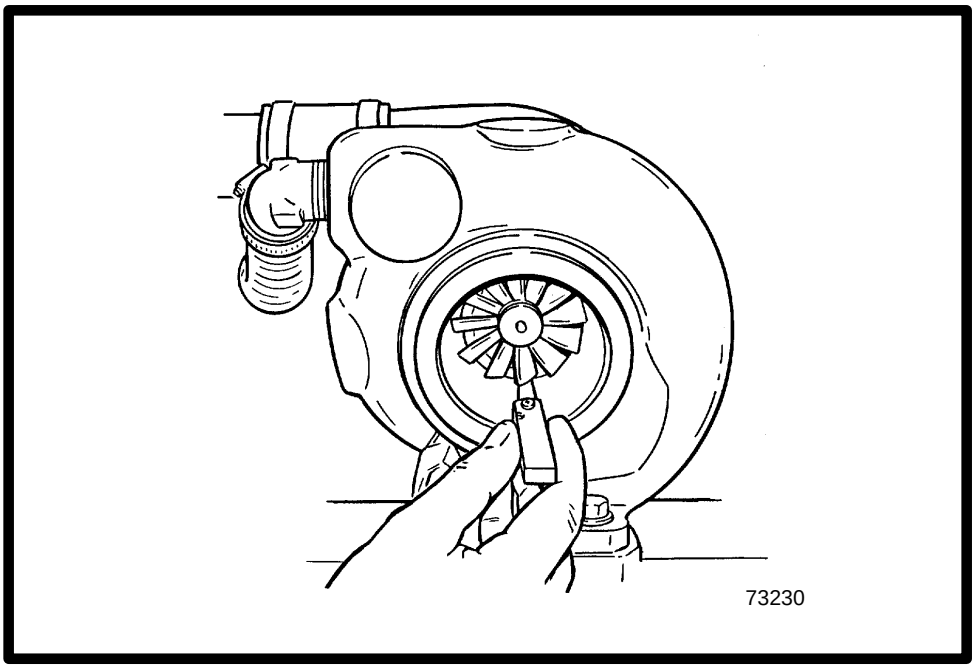
74127

Port Side Shown (Starboard Similar)

a - 90 Degree Fitting On Exhaust Manifold
b - Hose Clamp
c - Hose

5. Install exhaust cross-over manifold as previously outlined in this section.
6. Install turbo-charger on exhaust cross-over manifold. Refer to Section 7C.
7. Fill engine with coolant. Refer to Section 6B.

INTAKE AND EXHAUST SYSTEM



7
C

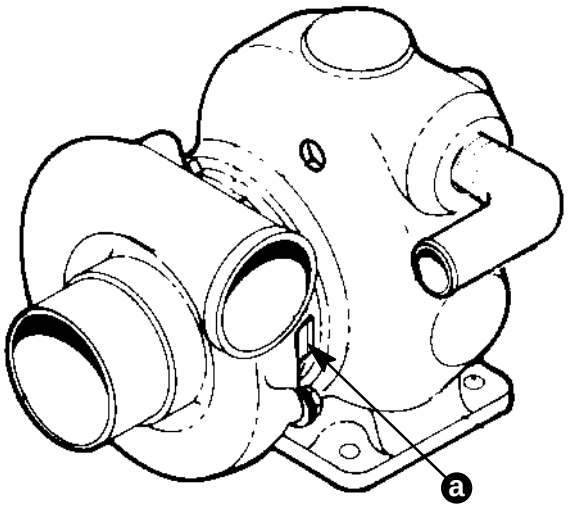
TURBOCHARGER

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Identification



73623

a - Identification Number Location

Turbocharger Specifications

Model		D7.3L/270
Manufacturer		Schwitzer
Type	Factory Part Number	3800 698M1
	Quicksilver Part Number	806015
Maximum Shaft Axial (end) Play		.002 - .005 in. (0.05 - 0.12 mm)
Maximum Radial (side) Play	Compressor End	.017 - .023 in. (0.43 - 0.58 mm)
	Turbine End	.016 - .024 in. (0.40 - 0.61 mm)
Maximum Boost at 3400 RPM		9 -11 PSI (62 - 75 kPa)
Engine RPM When Boost Starts (Approximately)		1500

Torque Specifications

Item/Fastener Location	Lb. In.	Lb. Ft.	N·m
Turbocharger Mounting Nuts		31	42
Exhaust Elbow Screws		21	28
Housing Clamps (At Turbocharger and Exhaust Elbow)	Tighten Securely		
90° Fittings and Boost Pressure Tube Fittings			

Sealants

Description	Part Number
Quicksilver RTV Sealer	92-91601--1
Quicksilver Perfect Seal	92-34227--1
Loctite Pipe Sealant With Teflon	Obtain Locally
Loctite 242	

Description

The D7.3L D-Tronic Diesel Engine is equipped with a turbocharger to boost intake pressure, resulting in increased horsepower. In one casing on the turbocharger housing exhaust gases are used to spin the turbine up to 100,000 RPM. The compressor, which is installed on the same shaft but in a separate casing, draws in filtered air, compresses it, and delivers it to the engine through the aftercooler.

The turbocharger bearings are lubricated by engine oil fed by a hose from the main oil gallery. Oil feed is returned to the engine through a pipe into an intake manifold valley pan orifice, which is sealed with a large grommet.

Coolant from the engine's closed cooled section cools the turbocharger housing, while the exhaust elbow is cooled by seawater flowing through it from the seawater cooled section.

Checking Turbine Bearings

NOTE: *Turbocharger internal parts are not available separately. If turbocharger components are faulty the complete turbocharger must be replaced.*

1. Check both compressor and turbine end blade-to-housing clearance by following appropriate instructions “a” and “b” :

   a. **To check compressor end blade clearance:**

      (1) Remove CDR breather tube hose clamp from aftercooler and slide tube from air cleaner.

      (2) Remove air cleaner.

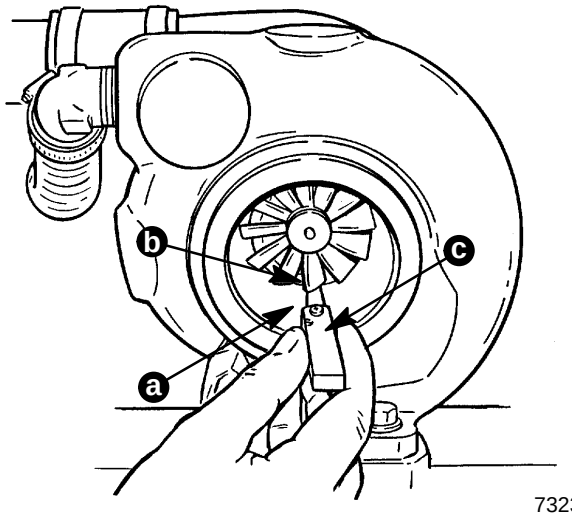
   b. **To check turbine end blade clearance:**

      (1) Refer to “Removing Exhaust Elbow or Riser” as outlined in this section.

      (2) Remove the exhaust elbow or riser.

2. Rotate the turbine impeller by hand to see that it turns smoothly. If not, turbine bearings or impeller problems exist.
3. Check if turbine blades are rubbing on housing. If they are, replace turbocharger.
4. Inspect turbine blades and housing for signs of burning or cracking. If these signs are found, replace turbocharger.
5. Using a feeler gauge as shown, check clearance between compressor or turbine blades and housing at two locations opposite one another. Clearance is the average of the two measurements and should be as shown following.

- **Compressor (Intake) End:** Clearance should be .017 - .023 in. (0.43 - 0.58 mm).
- **Turbine (Exhaust) End:** Clearance should be .016 - .024 in. (0.40 - 0.61 mm).

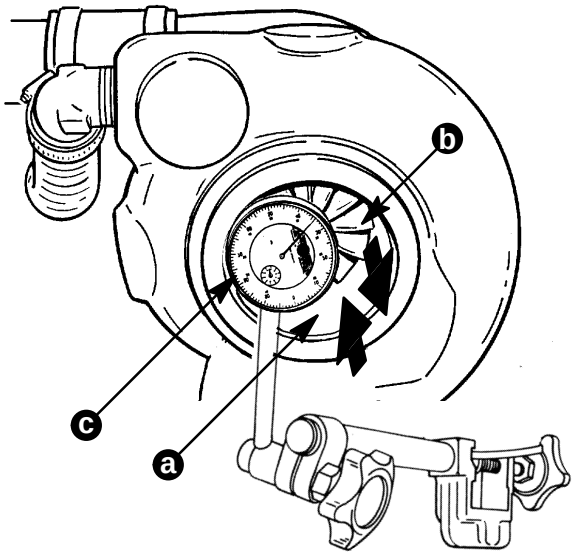


73230

a - Turbocharger Housing
b - Turbine Blades
c - Feeler Gauge

Checking Turbine End Blade Clearance Shown (Compressor End Similar)

6. Check axial (end) play on bearings by placing a dial gauge on the end of the shaft. Move the turbine shaft in the direction shown (“fore-and-aft”). Observe indicator needle. Measurement should be .002 - .005 in. (0.05 - 0.12 mm).



73230

a - Turbocharger Housing
b - Turbine Blades
c - Dial Gauge

Checking Bearing Axial (End) Play

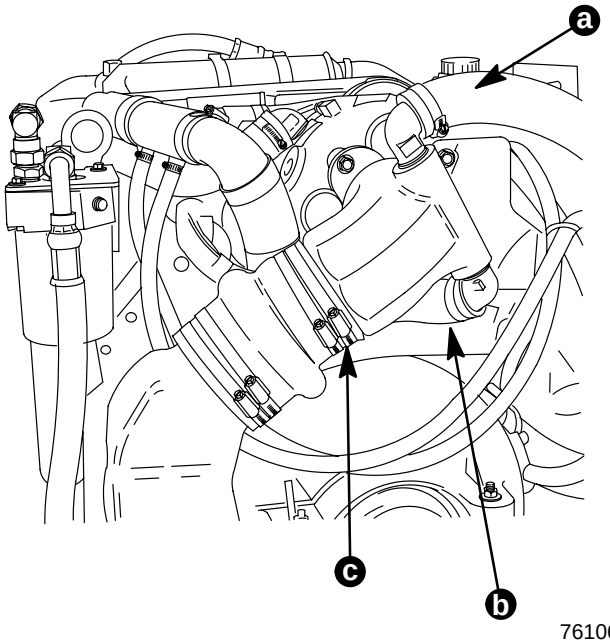
Removal

⚠CAUTION

Avoid possible injury or damage to equipment caused by an accidental short-circuit. Disconnect BOTH battery cables from battery before proceeding.

Removing Exhaust Elbow

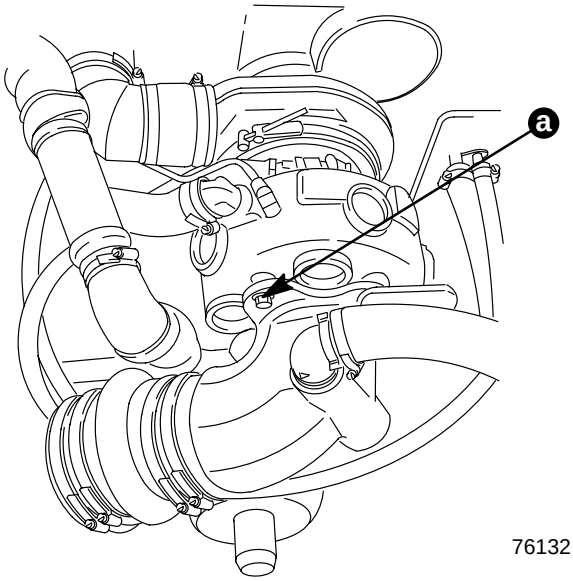
1. Disconnect battery cables from battery terminals.
2. Refer to SECTION 6A - “Draining Seawater Cooled Section” and drain the seawater section.
3. Remove the seawater hoses from the exhaust elbow.
4. Loosen the exhaust hose clamps on the exhaust elbow.



76106

a - Water Bypass Hose
b - Hose From Power Steering Fluid Cooler
c - Exhaust Hose Clamps

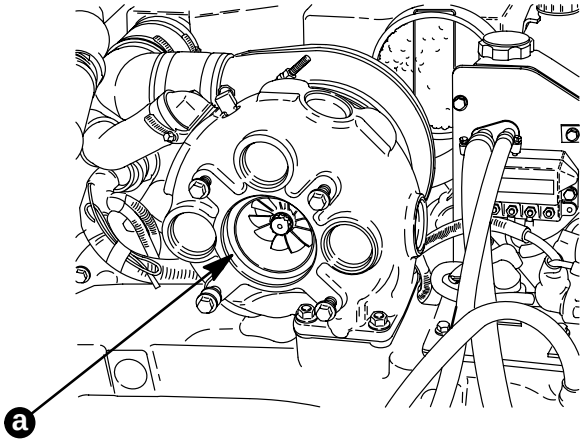
5. Remove the bolts from the exhaust elbow and turbocharger.



76132

a - Bolts (4)

6. Remove the exhaust elbow from the turbocharger. If existing exhaust elbow is to be reused, make matching marks to aid in alignment during assembly later.
7. Check and clean the surfaces on the turbocharger outlet.

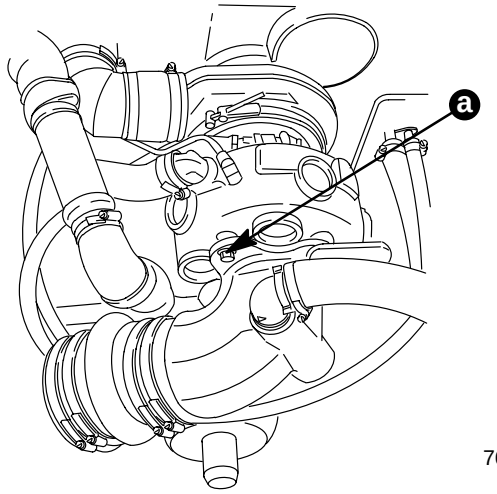


76142

a - Turbocharger Outlet

Installing Exhaust Elbow

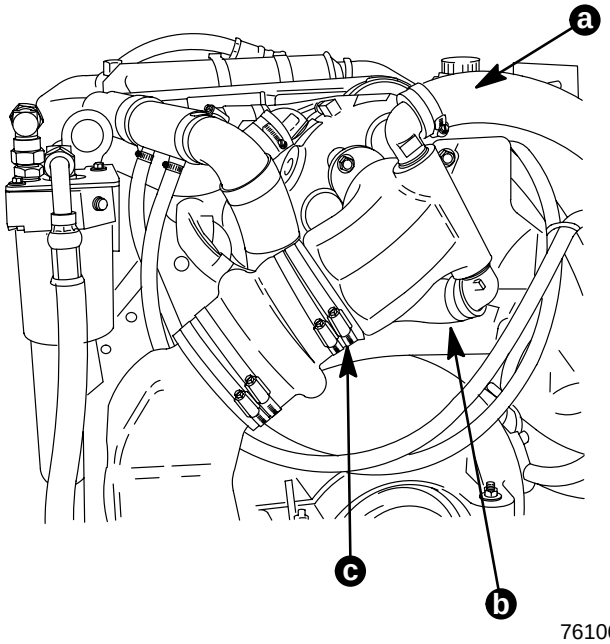
1. Install the exhaust elbow on the turbocharger. If existing exhaust elbow is being reused, align matching marks made during disassembly.
2. Install the bolts that secure the exhaust elbow to the turbocharger.
3. Securely tighten the exhaust elbow bolts at this time. Torque to 31 lb.ft. (42 N.m)



76132

a - Bolts (4)

4. Install the seawater bypass hose and the hose from the power steering cooler to the exhaust elbow as shown. Tighten the hose clamps securely.
5. Tighten the exhaust hose clamps on the exhaust elbow.



76106

a - Water Bypass Hose
b - Hose From Power Steering Fluid Cooler
c - Exhaust Hose Clamps

6. Connect battery cables to battery terminals.

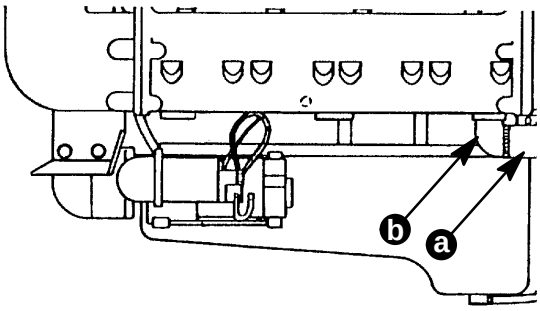
⚠CAUTION

Do not operate engine without cooling water being supplied to the seawater pickup pump, or pump impeller will be damaged.

7. Upon first starting engine, check for water or exhaust leaks and correct as needed.

Removing Turbocharger Unit

1. Drain exhaust manifolds by removing hoses from 90° fittings on port and starboard exhaust manifolds. Drain coolant into a suitable container.

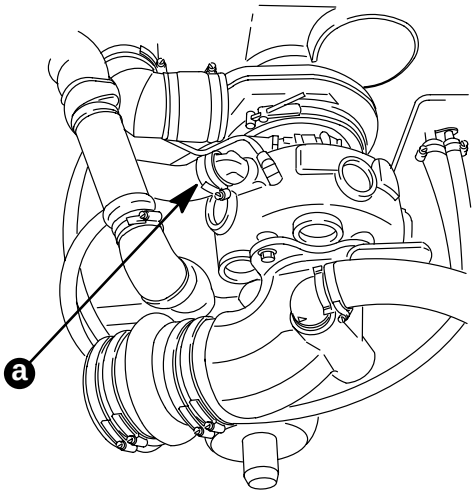


73255

Starboard Side Shown (Port Similar)

a - Manifold Hose (Port and Starboard Sides)

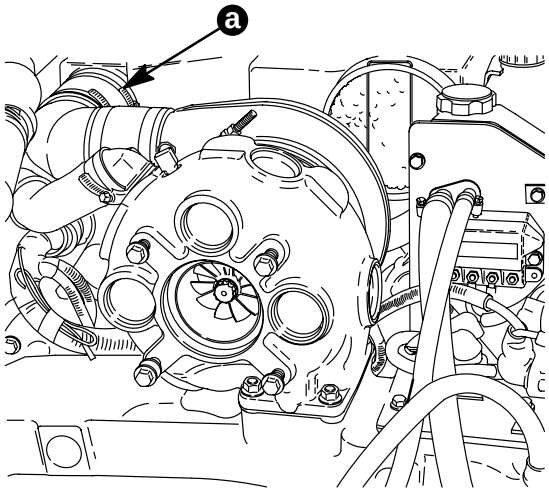
2. Disconnect turbocharger coolant hose from turbocharger 90° elbow on housing.



76132

a - Coolant Hose

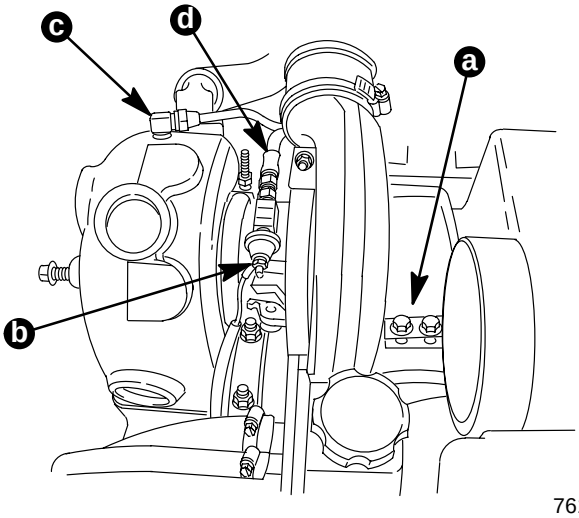
3. Remove exhaust elbow as previously outlined in this section. If existing exhaust elbow is to be re-used make matching marks to aid in alignment during assembly later.
4. Loosen hose clamps on hose between turbocharger and air horn.



76142

a - Rubber Hose And Clamps

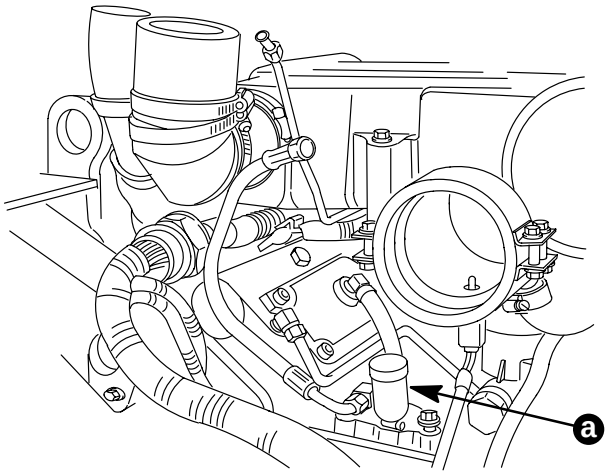
5. Disconnect turbocharger oil feed hose at fitting on turbocharger.
6. Disconnect clamp brackets on larger hose to aftercooler.
7. Disconnect wire from oil temperature alarm switch.
8. Disconnect coolant vent tube from fitting at top of turbocharger housing.



76143

a - Clamp Brackets
b - Oil Temperature Alarm Switch
c - Coolant Vent Tube
d - Oil Feed Line

9. Loosen hose clamp on the turbocharger coolant return hose connection in valley (beneath turbocharger).

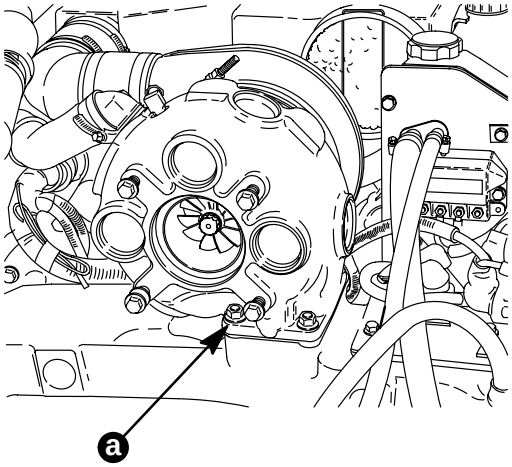


76149

Shown With Turbocharger Removed For Visual Clarity

a - Coolant Return Hose Clamp

10. Remove the four nuts with washers mounting turbocharger to exhaust crossover. Remove turbocharger.



76142

a - Nuts

Cleaning

IMPORTANT: Never use a caustic cleaning solution, as it may attack aluminum. Also, never use a wire brush which could damage impeller or mating surfaces.

1. BEFORE cleaning, inspect parts for burning, abrasion, carbon deposits, gas and oil leakage.

⚠CAUTION

Avoid injury. Always wear safety glasses when using compressed air.

2. Thoroughly clean all the parts with clean diesel fuel, using a soft brush. Dry with compressed air.

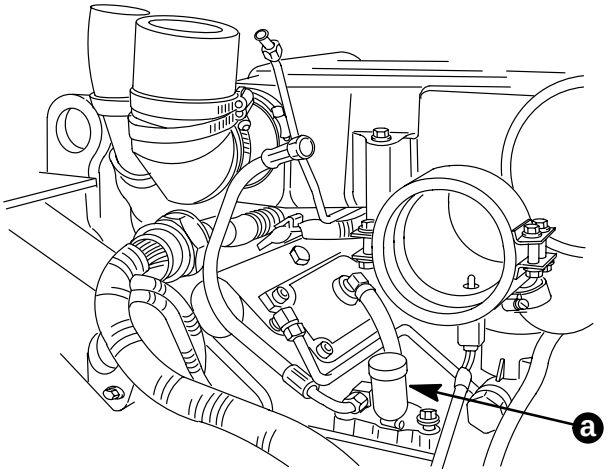
⚠CAUTION

Avoid injury, and damage to turbine bearings. When drying a cleaned unit using compressed air, DO NOT spin the turbine or allow turbine to spin, since no oil is being provided to the bearings.

Installation

1. If replacing the turbocharger, remove the following items from existing unit and install as shown:
   a. Apply Quicksilver Perfect Seal to the threads of the turbocharger oil feed hose 90° fitting and install. Tighten securely and position as shown.
   b. Apply Quicksilver Perfect Seal to the threads of the turbocharger coolant return hose 90° connector and install. Tighten securely and position as shown.
   c. Apply Quicksilver Perfect Seal to the threads of the coolant vent tube to fitting and install at top of turbocharger housing. Tighten securely.

2. Using a new gasket, install turbocharger by lowering it down on exhaust crossover while guiding coolant return hose onto connection from intake manifold valley.

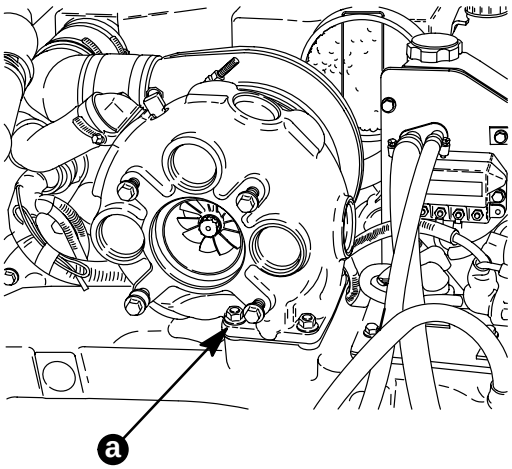


76149

Shown With Turbocharger Removed For Visual Clarity

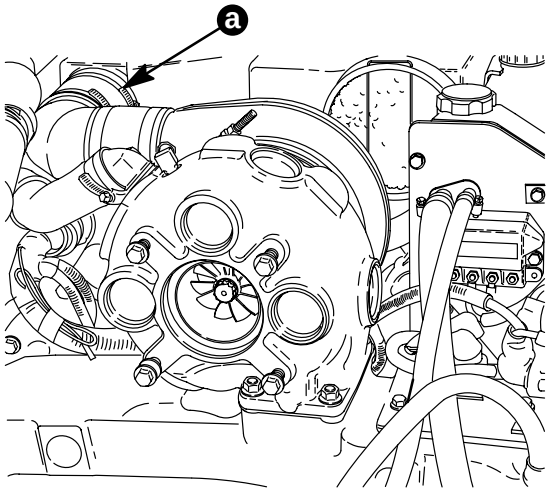
a - Coolant Return Hose Clamp

3. Install the four mounting nuts with washers. Torque nuts to 31 lb. ft. (42 N·m).



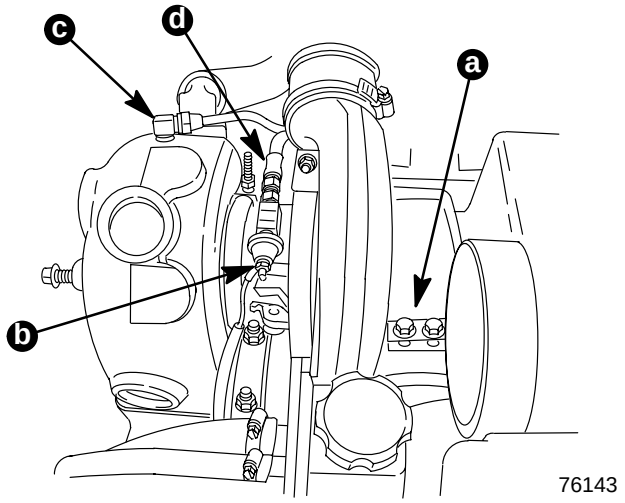
a - Nuts

4. Tighten hose clamps on coolant return hose.
5. Connect smaller diameter air hose to turbocharger and tighten hose clamps securely.



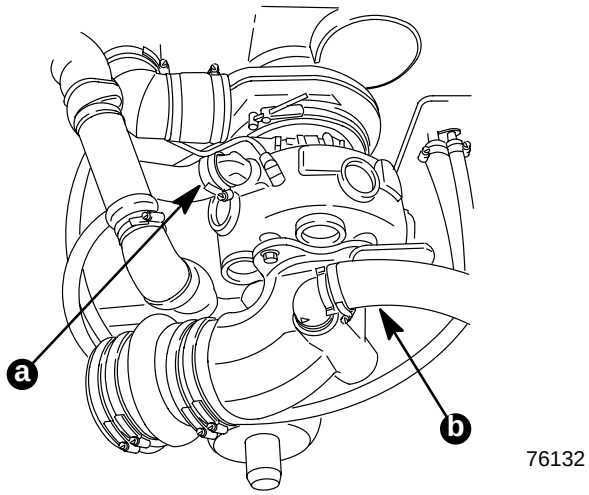
a - Rubber Hose And Clamps

6. Connect clamp brackets on larger hose to aftercooler.
7. Connect wire to oil temperature alarm switch.
8. Connect oil feed line at turbocharger housing and tighten union nut securely.
9. Connect coolant vent tube to fitting at top of turbocharger housing.



a - Clamp Brackets
b - Oil Temperature Alarm Switch
c - Coolant Vent Tube
d - Oil Feed Line

10. Connect coolant hose to turbocharger housing 90° connector and tighten hose clamp securely.



a - Coolant Hose
b - Overboard Discharge Hose

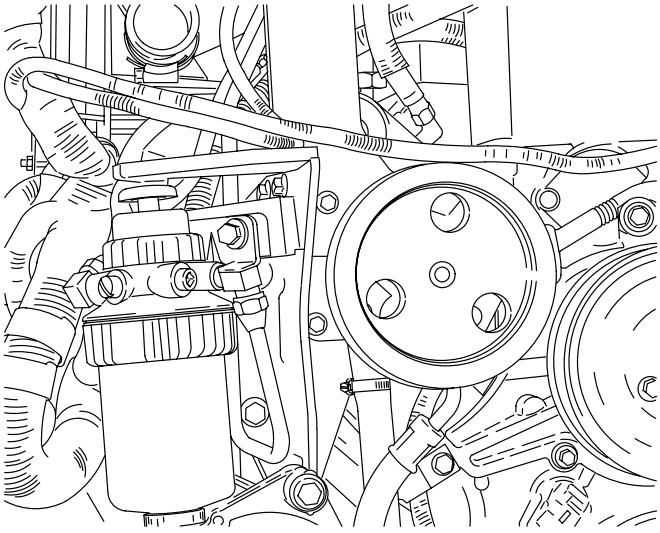
11. Refer to “Installing Exhaust Elbow” and install exhaust elbow as outlined. Align matching marks made during disassembly.
12. Connect overboard discharge hose and tighten clamp securely.
13. Fill closed cooled section following instructions in Section 6B - “Closed Cooled Section - Filling Closed Cooled Section.”
14. Connect battery cables to battery by FIRST installing positive (+) battery cable end on positive (+) battery terminal. Tighten clamp securely. THEN install negative (-) battery cable end on negative (-) battery terminal. Tighten clamp securely.
15. Crank engine intermittently until oil pressure registers on oil gauge. DO NOT engage starter for more than 15 seconds at one time. Allow at least one minute for starter to cool before reusing.

⚠CAUTION

Do not operate engine without cooling water being supplied to the seawater pickup pump, or pump impeller will be damaged.

16. Start engine and check for water and exhaust leaks. Correct as needed.

POWER STEERING



76140

PUMP AND RELATED COMPONENTS

8

A

Index

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Torque Specifications

Item/Fastener Location	Lb. In.	Lb. Ft.	N·m
Front and Rear Tensioning Screws	84		10
Reservoir Mounting Bracket Special Stud	72		8
Fluid Pressure and Return Line Fittings		20-25	27-34
All Fasteners Not Listed	Tighten Securely		

Lubricants / Sealants

Item/Description	Part Number
Quicksilver Power Trim and Steering Fluid	92-90100
Automatic Transmission Fluid - Dexron, Dexron II, Dexron II-D	Obtain Locally

IMPORTANT: Power Steering Pumps are considered non-repairable units and are intended to be removed and replaced by new units.

Description

The Power Steering system utilizes an engine-driven, van-type hydraulic pump. The pump supplies fluid flow and pressure by means of hoses to a control valve. The control valve, in turn, controls fluid flow and pressure to-and-from a boost cylinder control valve mounted on the boat transom.

Refer to appropriate MerCruiser Stern Drive Service Manual for additional information and procedures on the complete power steering system, if not covered in this section.

Maintaining Power Steering Pump Fluid Level

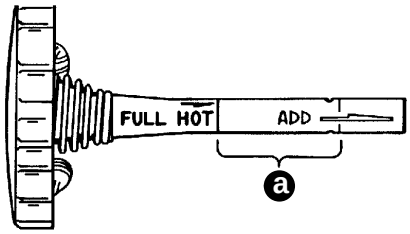
IMPORTANT: Use only Quicksilver Power Trim and Steering Fluid, or Dexron II automatic transmission fluid (ATF), in power steering system.

⚠CAUTION

DO NOT RUN POWER STEERING DRY, or pump will be damaged.

WITH ENGINE WARM

Level should be between the FULL HOT mark and ADD mark on dipstick.



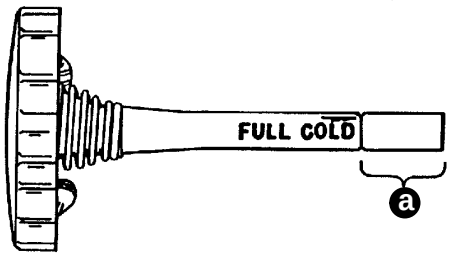
72518

a - Proper Fluid Level with Engine Warm

If level is below ADD mark, but fluid is still visible in pump reservoir, add required amount of Quicksilver Power Trim and Steering Fluid or automatic transmission fluid (ATF), Dexron, or Dexron II, through fill cap opening, to bring level up to FULL HOT mark on dipstick. DO NOT OVERFILL.

WITH ENGINE COLD

Level should be between FULL COLD mark and bottom of dipstick.



72519

a - Proper Fluid Level with Engine Cold

If level is below bottom of dipstick, but fluid is still visible in pump reservoir, add required amount of Quicksilver Power Trim and Steering Fluid or automatic transmission fluid (ATF), Dexron, or Dexron II, through fill cap opening, to bring level up to FULL COLD mark on dipstick. DO NOT OVERFILL.

Filling and Bleeding Power Steering System

IMPORTANT: Power Steering Systems MUST BE filled exactly as explained, in the following, to be sure that all air is bled from the system. All air must be removed, or fluid in the pump may foam during operation and be discharged from pump reservoir. Foamy fluid also may cause POWER Steering Systems to become spongy, which may result in poor boat control.

1. Position drive unit straight back. Remove cap from power steering reservoir and check fluid level with the attached dipstick.
2. Add Quicksilver Power Trim and Steering Fluid or Dexron ATF to bring fluid up to the correct level.
3. With the engine NOT running, turn the steering wheel at a moderate rate, back-and-forth, to end of travel for a few seconds to allow any air to bubble from pump reservoir. Do this a minimum of 5 complete cycles. Recheck fluid level and add if necessary.
4. Install reservoir cap.
5. Position boat in the water or see that water is supplied to seawater pickup holes in gear housing.
6. Start engine and run at IDLE. During this time, turn steering wheel back-and-forth to end of travel in each direction several times.
7. Position drive unit so that it is straight back and then stop the engine. Remove the reservoir cap. Allow any foam in the reservoir to disperse, then check fluid level and add fluid if needed. DO NOT OVERFILL. Install and tighten the cap securely.
8. If fluid was foamy in Step 6., repeat Steps 6 and 7, until the fluid does not foam and the level remains constant.

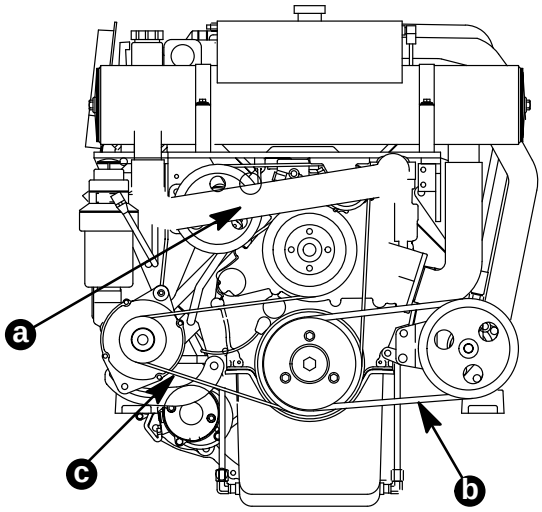
NOTICE

For more information on power steering system and components refer to appropriate MerCruiser Stern Drive Service Manual.

Pump Assembly

Removal

1. Remove belts. Refer to Section 1B.
2. Drain the seawater from the cooling system. Refer to Section 6A.
3. Drain coolant from the closed side of the cooling system. Refer to Section 6B.
4. Remove the front hose from the heat exchanger.



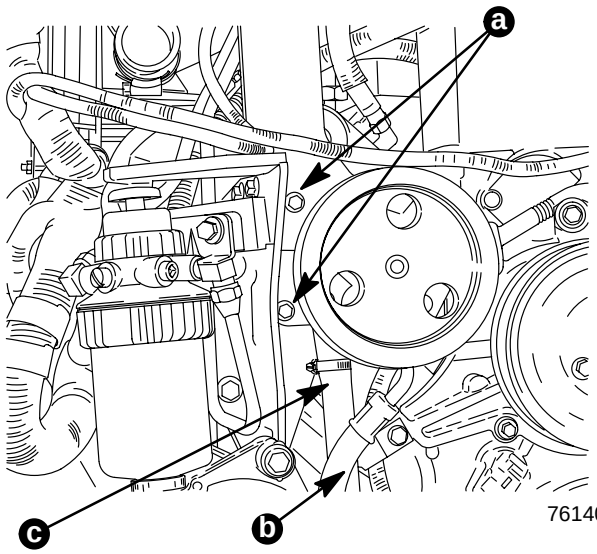
76186

a - Coolant Hose
b - Seawater Pump Belt
c - Accessory Drive Belt

5. Remove screws that secure the pump.

NOTE: *Use a suitable plug to prevent the power steering reservoir from draining completely.*

6. Remove fluid return hose from power steering pump and plug with a suitable plug.
7. Remove and plug fluid pressure hose from power steering pump.



76140

a - Coolant Hose
b - Pressure Hose
c - Return Hose

Installation

1. Connect the return hose to the pump and secure with hose clamp.
2. Connect the pressure hose to the pump and tighten the fitting securely.
3. Install the pump.
4. Torque fasteners to 84 lb.in. (10 N.m).
5. Reinstall drive belts and adjust tension. Refer to Section 1B.
6. Refill the cooling system. Refer to Section 6B.

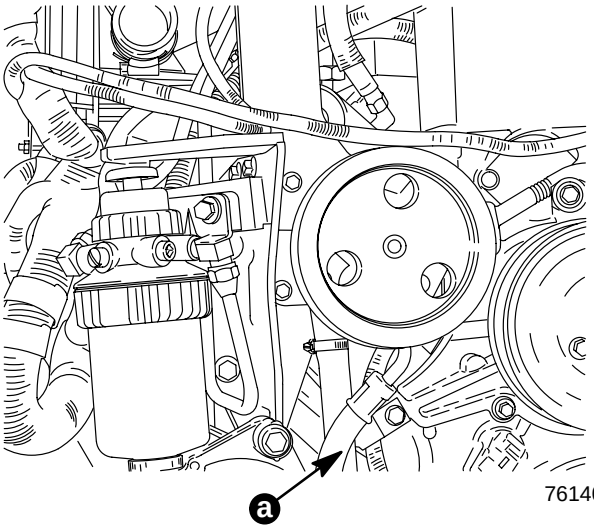
Hydraulic Hoses and Power Steering Fluid Cooler

IMPORTANT: Make fluid connections as quickly as possible to prevent fluid leaks.

High Pressure Hose (Pump to Control Valve)

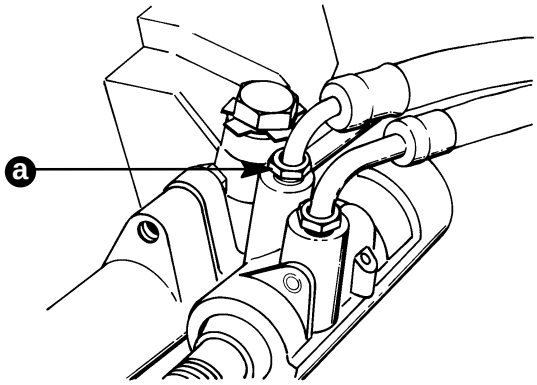
REMOVAL

1. Remove high pressure hose fitting with O-Ring seal from power steering pump.



a - Fluid Pressure Line

2. Remove hose and note hose routing to control valve.
3. Remove hose fitting from control valve.



a - Rear Fitting (Fluid Pressure Hose)

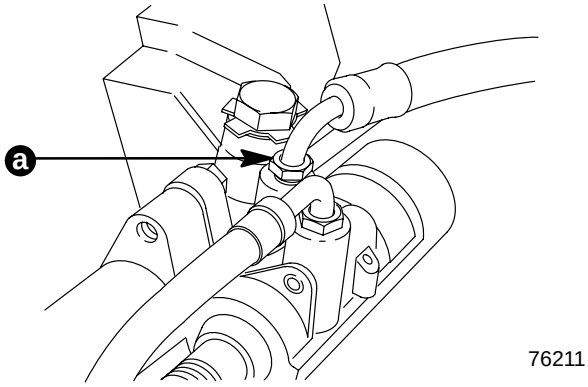
INSTALLATION

⚠CAUTION

Route hoses as shown. This will help avoid stress on the hose fittings and prevent kinks in hoses.

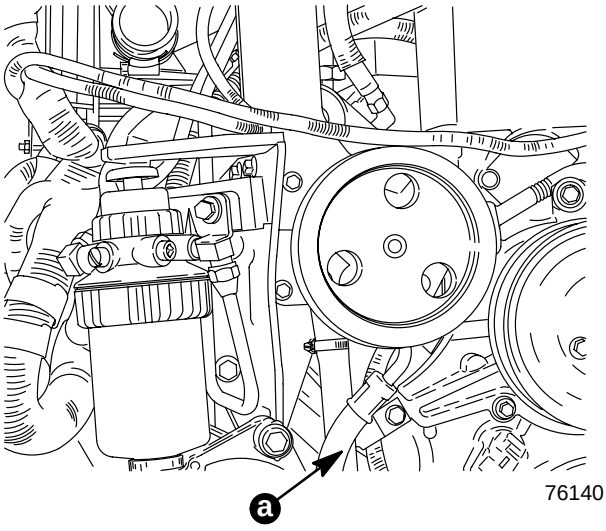
IMPORTANT: Be careful to not cross thread or over-tighten hose fittings.

1. Thread high pressure hose in control hose valve and position hose as shown below. Torque fitting to 20 - 25 lb. ft. (27 - 34 N·m)



a - Rear Fitting (Pressure Hose)

2. Route hose as previous noted in removal, secure with sta-straps if necessary.
3. Ensure there is a new O-Ring on high pressure hose end. Install fitting into power steering pump.



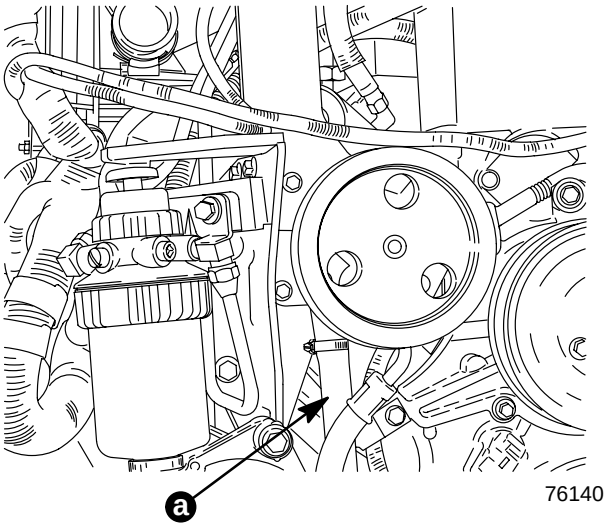
a - Fluid Pressure Line

Low Pressure Hose (Cooler to Pump)

REMOVAL

NOTE: *Catch fluid that drains from from hose, cooler and pump in a suitable container.*

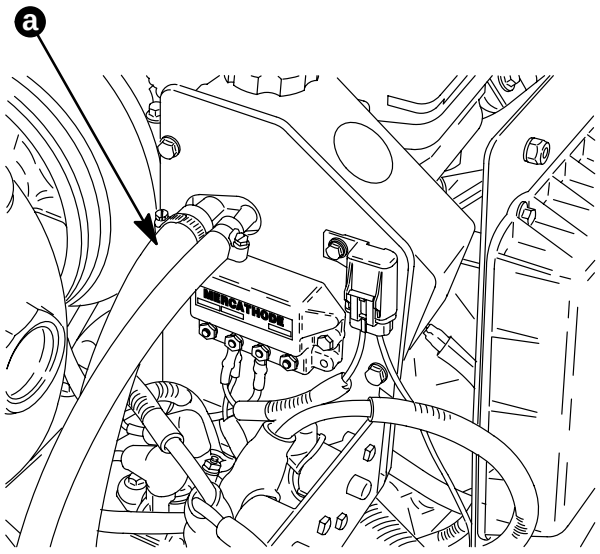
1. Loosen hose clamp and remove fluid return hose from power steering pump.



76140

a - Fluid Return Line

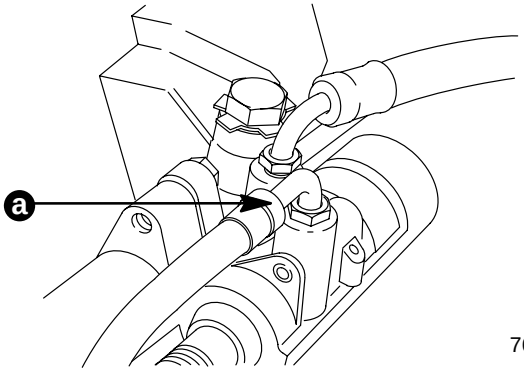
2. Loosen clamp and remove fluid return hose from fluid reservoir.



76134

a - Fluid Return Hose to Fluid Reservoir Location

3. Remove and note routing of fluid return hose from fluid reservoir to control valve.



76211

a - Fluid Return Line

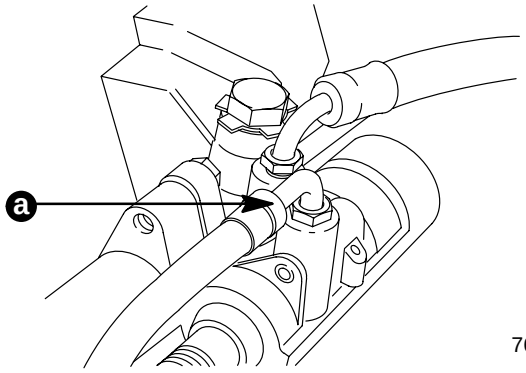
INSTALLATION

⚠CAUTION

Route hoses as shown. This will help avoid stress on the hose fittings and prevent kinks in hoses.

IMPORTANT: Be careful to not cross thread or over-tighten hose fittings.

1. Install fluid return hose on power steering pump and fluid reservoir. Tighten hose clamps securely.
2. Install fluid return hose in control valve and torque fitting to 20 - 25 lb. ft. (27 - 34 N·m).



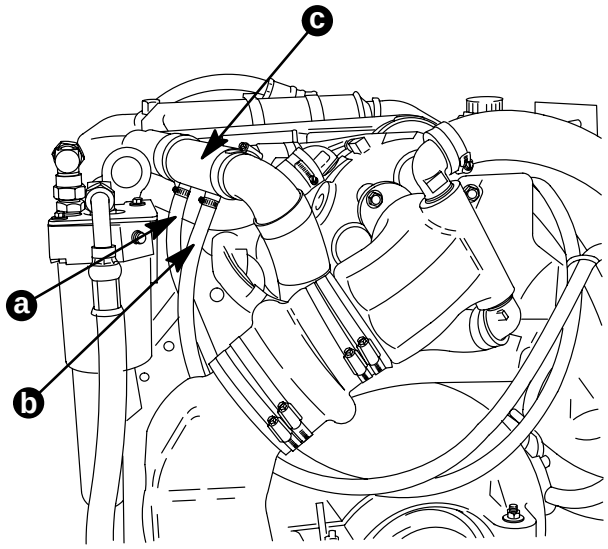
76211

a - Fluid Return Line

3. Route fluid return hose as previous noted from control valve to fluid reservoir. Tighten hose clamp securely.
4. FIll and air bleed system. Refer to Filling and Bleeding Power Steering System" in this section.

Power Steering Fluid Cooler

Refer to SECTION 6A - “Coolant Tank/Heat Exchanger, Oil, Power Steering and Transmission Fluid Coolers” for information on removal, cleaning and installation of the power steering fluid cooler.



76106

a - Return Line To Fluid Reservoir
b - Return Line From Control Valve
c - Power Steering Fluid Cooler